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PAPERS, REPORTS, DISCUSSIONS, AND MEMOIRS

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MILWAUKEE, WIS., JULY 10-11, 1929

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RELATION BETWEEN RAIL AND WATERWAY TRANSPORTATION

WATERWAY TRANSPORTATION FROM THE VIEWPOINT OF OPERATION

By Maj.-Gen. Thomas Q. Ashburn,* U. S. A.

In developing this, the opening paper of the session, General Ashburn delved into early history. As he interpreted the Biblical record:

"The original, ardent, dyed-in-the-wool advocate of water transportation was Noah; the prototype of the modern barge was the ark, and the first satisfactory terminal was Mount Ararat.

"Noah was a common carrier; he advertised that he would sail at a certain date and carry certain commodities, and he did. Like his descendants who advocate the full utilization of water as a means of transport as a necessity, he was sneered at, opposed, and accused of being a 'one-ideaed' man; in other words, a 'nut'.

"From the time he laid the keel of the Ark till the time when the floodgates of heaven were opened and the rains descended and the floods came he was surrounded by wise men who counseled him: 'See here, Noah, old top, you're never going to need this thing, even if it does float on the water (and we don't think it will), how are you going to steer it, and where are you going? Haven't we got our legs and our beasts of burden as means of transportation? What was good enough for our fathers is good enough for us. Stop spending your good simoleons and wasting your time over something which, at the best, is only an experiment and will never be needed anyhow! Take our advice, old man, and quit while the quitting is good!'

"But old Noah kept hammering away. He didn't know where he was going, but he did know there was going to be need of water transportation—and he was right. A more unlikely seaport than Mount Ararat would be hard to imagine, and yet it did become, so far as history records, the first and most successful seaport in the world."

Necessity Develops Transportation.—Modern man, like Noah, continued General Ashburn, has been struggling with the question of water transportation and has succeeded in dumbfounding his critics. The expansion of civilization has been coincident with that of transportation. In fact, almost all communication between individuals, between communities, between States and Nations, is some form of transportation.

* Chairman and Executive, Inland Waterways Corporation, Washington, D. C.

Every demand for necessities, comforts, and luxuries requires transportation in some form; Nature has not provided these supplies at the point of consumption. In the attempt to obtain cheap raw material and low cost of distribution, seaports have been developed. Thus, asserted General Ashburn,

"The sea is an universal highway, and the cheapest means of transportation known is by the sea. * * * Consequently, every inland city, located upon a navigable waterway, dreams of the time when it shall be an inland seaport".

Three Distinct Problems.—Actually, the navigable inland waterways divide themselves among the Great Lakes, improved rivers, and canals. As these are publicly built and maintained, the user is not concerned with their cost as long as they are free to him:

"He accepts the situation as it is, and leaves to economists, statisticians, and college professors, the academic question of whether the Congress was right or wrong in spending money for such purposes. He says, in effect, 'The Government may have been right or wrong in spending money to create these channels, but so long as the money has been spent, it has been spent, and academic discussion does not concern me; what does concern me is whether I can profitably operate upon the channels which have been created by the Government by the expenditure of such funds.' "

Differences in size, draft, and current, however, create distinct problems in waterways. Hence, in order to make the treatment concrete, General Ashburn chose the Great Lakes, the New York Barge Canal, and the Lower Mississippi River for specific reference, each as representing a type.

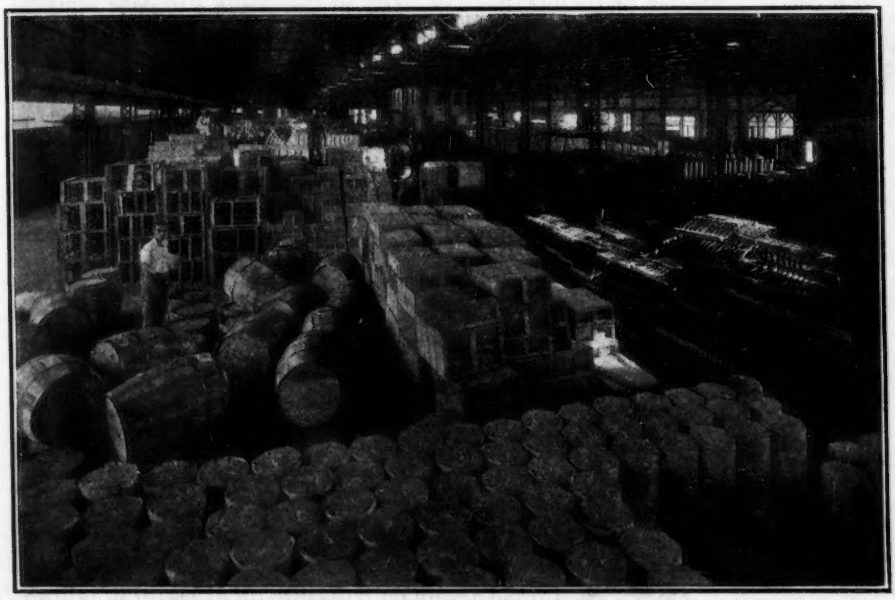
Lengths of Season and Difference of Equipment.—In each instance the climate has its marked effects. It limits the period of operation on the Great Lakes to eight months per annum, likewise on the Barge Canal; on the other hand, the Lower Mississippi is open the entire year. Hence, the shortened seasons "require the accumulation of enough profits in eight months to make a reasonable return upon the investment for a whole year, or that some other use of the equipment must be found during the closed season".

To make the treatment still more general and to give comparative costs only, these particular waterways were chosen as the best existing type of travel in each case. General Ashburn further assumed that "certain conditions which do not now exist, will eventually exist, in order to arrive at what will be the eventual cost per ton-mile, when the situation is practically perfected."

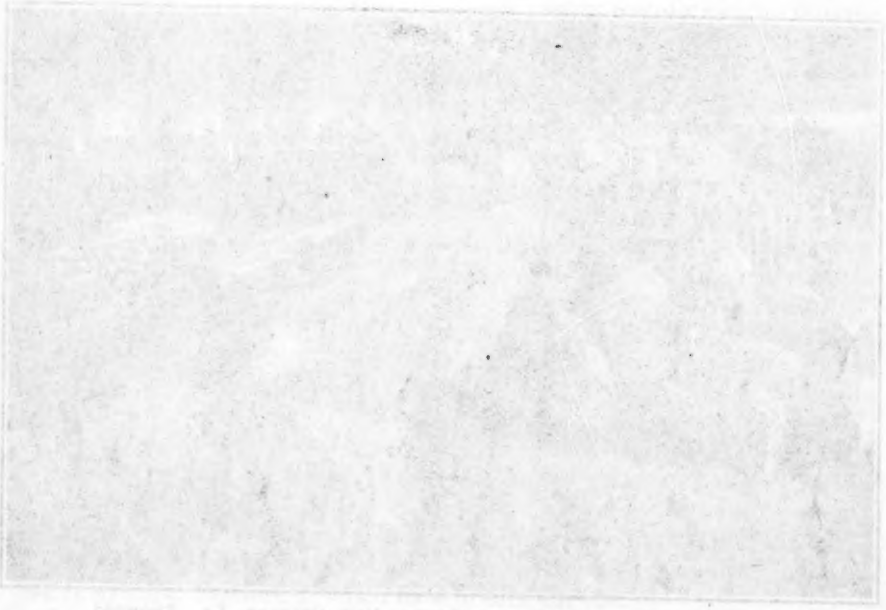
Using as the most practicable single unit for lake transportation a 16 000-ton steamer with an average speed of 10 miles per hour, plying between Cleveland, Ohio, and Duluth, Minn., and capable of carrying coal from Cleveland to Duluth and iron ore in the reverse direction, he found the cost of such a steamer to be $1 500 000, which, at 6% return and 3% depreciation, would require $135 000 per annum. This amount has to be earned within eight months.

Similarly, for the Barge Canal, a self-propelled barge of 300 tons capacity and capable of pushing seven other barges of 500 tons capacity each, would cost about $400 000. This, then, would require earnings of $36 000 per annum, with eight months' service. On the Lower Mississippi, a towboat with eight barges could handle 16 000 tons down stream and would cost $650 000. In twelve months, therefore, it would have to earn $58 500.

SELF-PROPELLED BARGE, MUNICIPAL WHARF, ST. LOUIS, MO., SHOWING METHOD OF LOADING AND STOWING FREIGHT.



INTERIOR OF BIENVILLE STREET WHARF, NEW ORLEANS, LA., SHOWING CLASSIFICATION OF FREIGHT.



Continuing, General Ashburn showed how difficult it was to make a reasonable comparison between the three routes. For example, a lake steamer plies its trade equally well in either direction; on the other hand, a Mississippi steamboat may transport twice as much material down stream as up stream and at one-half the expenditure for fuel. Of course, the length of haul will vary for each case; however, it is assumed that all deliveries of cargo are made at a single port of call. Thus, the variables are reduced to the fewest possible numbers.

Comparative Round Trip Costs.—Taking for his analysis a typical lake steamer working between Cleveland and Duluth, he showed in detail how it could operate successfully at 0.84 mill per ton-mile. Theoretically, the cost might be as low as 0.64 mill. Similar computations served for the other routes so that:

"Summing up, a theoretically successful operation by lake could be carried on with an operating income of 0.64 mill per ton-mile, the Lower Mississippi with 1.7 mills per ton-mile, and the New York Canal with 3 mills per ton-mile."

Justifying this detailed treatment, he mentioned the tendency in public discussion to assume lake costs as the ultimate charges for water transportation, on the one hand, and for opponents of waterways to quote the Erie Canal as the great failure for judging all river transportation, on the other hand.

So much for the theoretical or ideal situation. General Ashburn then went on to mention the types of carriers which might be utilized and their advantages.

Value of Various Carriers.—Private and contract carriers, which have definite routes, termini, and customers, should be supplemented by common carriers that will undertake to serve any one who offers business. Thus, any menace of utilization by private or contract carriers alone "can be absolutely neutralized by powerful and efficient common carriers, and such joint utilization will result in the greatest good for the greatest number".

Such a common carrier, however, will have expenses from which the other type will be free: It has to have an extensive organization with offices at every port. This means a large "overhead", which is more or less independent of the extent of its operation. Again, it requires tremendous financial resources, as an economical operation calls for equipment such as few private corporations could furnish.

To combat possible misuse, it is necessary to have a great common carrier. In practice, this has meant "a governmentally owned corporation, functioning as a private corporation, but backed by the great powers of the Government itself."

The common carriers visualized would be of nation-wide benefit and would not necessarily operate by water alone. They would be organized "much like good railroads" with experts as heads of various departments. Costly equipment and powerful financial backing are presupposed. All these considerations impelled Congress to set up the present Inland Waterways Corporation, which might demonstrate the possibility of success and thus encourage private capital to invest in an operation no longer hazardous.

Expenses of Government Operation.—To show the resultant costs for this Corporation, General Ashburn presented statistics as follows:

"THE BARGE LINE DOLLAR

"WHERE IT CAME FROM AND WHERE IT WENT

"Calculated on the Total Revenues and Total Expenses of the Operating Divisions of the Inland Waterways Corporation.

	1927	1928
"Where the dollar came from:		
Total revenues	$0.997	$1.00
Operating deficit covered by Corporation	0.003	
	$1.00	$1.00
"Where the dollar went:		
Maintenance and operation—Line vessels	0.439	0.403
Maintenance and operation—Terminals	0.407	0.393
Traffic expenses	0.045	0.041
General expenses	0.045	0.049*
Loss and damage	0.032	0.029
Maintenance and operation—Railroad	0.021	0.021
Charter expenses	0.011	0.005
Net income	....	0.059
"Total	1.00	1.00 "

The high cost of the terminals results largely because they are owned locally, but operated and maintained by the Waterways Corporation. With the increase in traffic, the relative expense will greatly decrease. In addition, the possible use of terminals for local business will greatly help. Still another item, of course, is the inability to standardize the terminals, for example, there was no such thing as a "standard barge".

Results of Government Operation.—Another handicap lies in the nature of the business, because cargoes can only be received at certain ports, whereas rail or motor transportation is free from such limitations:

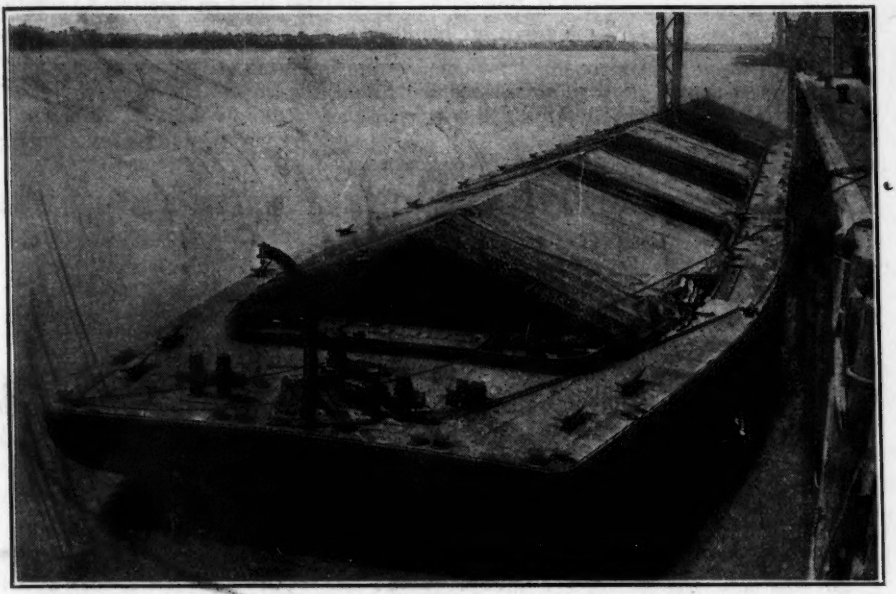
"There thus results in our operations a costly transfer from car or truck to barge, or *vice versa,* and sometimes a second costly transfer, where the freight originates on a rail line, is transferred to barge, and again to rail."

* * * * * * * *

"When the point of origin is a river port, and the destination is a river port, and the same barge can carry its cargo from point of origin to point of destination, then and then only, can water transportation offer a comparable service to an all-rail service."

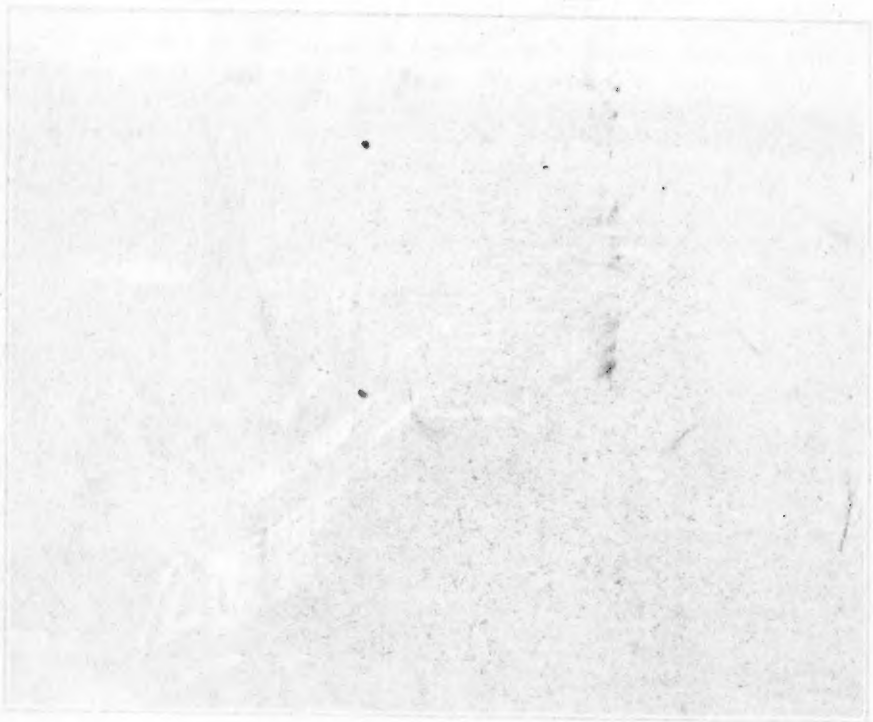
With such conflicting interests involved, it has been a difficult matter to show waterways transportation in a favorable light and thus induce others to enter the field. However, experience has demonstrated convincingly that the

* The increase in general expenses of 1928 over 1927 of 4 mills on the dollar was due to:
(*a*) Higher cost of insurance due to tonnage increase and greater protection.
(*b*) Salaries and expenses of upper river officials.
(*c*) Increased office rent and expenses at New Orleans, La.



STEEL BARGE WITH 70,000 BUSHELS OF GRAIN, INLAND WATERWAYS CORPORATION.

STERN-WHEEL STEAMER AND TOW, MISSISSIPPI RIVER.



policy of Congress in thus setting up the Inland Waterways Corporation was far-sighted and the people have demanded its extension, for,

"They have seen its practical effects, cheaper transportation for all through co-ordination of rail, water, and motor transportation, with an accruing revenue to the joint carriers which, when fairly divided, will afford each participating carrier a reasonable living revenue."

RELATION BETWEEN RAIL AND WATERWAY TRANSPORTATION IN THE UNITED STATES

By E. A. Hadley,* M. Am. Soc. C. E.

In introducing his subject, Mr. Hadley chose to limit his comparisons to the railroads and the larger inland rivers. He showed how waterways were originally the natural mode of transportation, but the Civil War interrupted their normal development and forced the extension of the railroads, which, thereafter, more or less superseded the waterways. Thus, it was steam, in one form of application or another, which really developed transportation.

Early Conditions.—Even in the early days, however, transportation rates were higher than those now charged. Thus, bulk shipments of grain between the "Twin Cities", in Minnesota, and Chicago, Ill., now cost less than did the single charge for sacking alone before the Civil War. As a result, special barges had to be built so that following reconstruction days there was an admirable co-ordination between rail and water transportation.

To obviate the necessity for transferring from barges to railroad cars and to serve the rapidly enlarging agricultural districts, railroads had to be extended and thus gradually took away the business from the waterways. To-day, Mr. Hadley believes, no other medium can handle these enormous crops and raw material. In fact,

"The rivers do not produce any new traffic, but that which they do haul is taken away from the railroads. * * * It is questionable whether inland water transportation on the rivers can be revived and improved to such an extent as to enable it to compete successfully with the railroads of to-day."

Public Funds for Transportation.—Whatever may be the railroad rates, river charges will always be lower, and hence no incentive is given to the railroads further to lessen their rates as is so often argued. In addition, the Government places restrictions on the railways in the form of limited profits. It goes still further by subsidizing competition in the form of improved highways and waterways for general use, free from charge or from regulations.

In considering this situation Mr. Hadley believes strongly that,

"It is the privilege of the American people to undertake the development of any transportation agency they desire, but the principles of our Government should enable us to keep in mind the fact that we cannot expend the money of all the people for the development of an enterprise which due to its location can be helpful to but a small portion of the people and then only by doing great injury to another branch of the same industry upon which all of the people must depend."

* * * * * * * *

* Chf. Engr., Mo. Pac. R. R., St. Louis, Mo.

"The railroads cannot be discarded and must be supported and any arrangement entered into by the Government whereby the public pays more for transportation and the individual shipper less is not economically sound."

Handicapping Railroads in Favor of Waterways.—Admittedly, the Great Lakes furnish remarkably cheap transportation and show tremendous economy with respect to the expenses for waterways improvements. However, "nothing approaching this situation can be said of the river transportation as now sponsored by the Federal Government."

As contrasted with the waterways, Mr. Hadley showed how railroads pay the tremendous sum of $400 000 000 yearly in taxes alone. In addition, they furnish and maintain expensive rights of way and structures.

Equalization as between the two forms of transportation would give certain remarkable results. For example,

"If all the costs incurred by the Government through its various departments to maintain navigation on our rivers were assembled and charged against the cost of operation of the barge lines, the cost per ton of freight transported by the barges would be shown to be so enormous that its realization would doubtless discourage further development along these lines.

"If the railroads were relieved of taxes and the cost of maintenance of roadway and had their terminals provided at the expense of the large cities, as is now done for the barge line service, there is no doubt but that their rates could be reduced far below the rates now charged by the barge lines.

* * * * * * *

"The railroads not only lose the traffic handled by the river, but see a part of their annual tax payments go toward paying the cost of supporting their Government operated competitor.

"The real question at issue regarding the proposed further development of inland waterways is whether or not the cost of transportation to the public as a whole will be decreased or if only individual shippers would benefit by this service, the deficits through operation and the cost of the improvement work to be paid from taxes or buried in the records of other departments of the Government. If the benefit is to accrue to individual shippers only then it is unfair to the balance of the people."

Costs of Waterways.—It is only fair, claimed Mr. Hadley, to state the cost of water transportation including the subsidies paid by the people as a whole. Not until the business can make a profit, including these investments, taxes, and maintenance, will private capital be interested in waterways operation. Further,

"It cannot be considered sound public policy to reduce railroad earnings, impair railroad credit, and render railroad service inadequate, in order that a field may be provided for water services, which at best can and should be only supplementary to the railroads."

Coming to the question of expenditures, Mr. Hadley quoted authorities to show that the estimated cost of the St. Lawrence Waterway ($260 000 000), would be sufficient to build three double-track lines between Chicago and Boston, Mass. These railroads, however, would carry twenty-four times as much freight as waterways.

Then, there is the New York State Barge Canal. This canal,

"Costs the taxpayers of New York State nearly $11 000 000 per year and the people of New York State would have saved approximately $4 500 000 if all

the freight had been handled by the railroads with the State paying the charges, and the shippers would have saved about $3 000 000."

Summarizing his attitude as representative of the railroads of the United States, Mr. Hadley asserted that:

"The railroads as a whole are not opposed to river transportation if it can be successfully conducted without being subsidized and they have co-operated in a constructive manner in the provision of port terminal facilities and in the application of joint rates. They should not, however, be compelled to meet a competition that cannot stand alone and further expenditures by the Government to extend river transportation will certainly have to come out of revenues received from taxes, which are already burdensome enough."

RAILWAYS VERSUS WATERWAYS: AN ECONOMIC COMPARISON

By L. D. Cornish,* M. Am. Soc. C. E.

At the very outset, Mr. Cornish stated the basis for his study:

"The history of mankind", he asserted, "shows conclusively that the predominating influence in the rise and fall of nations and cities has been the relative cost of transportation. * * * The easy conveyance of commodities in these and future days means cheap transportation facilities, and in the United States the ease of transportation is now measured by freight rates in mills per ton-mile."

Relative costs for shipments during 1924 and 1925 show freight rates per ton-mile of 11.32 mills for freight, 1.2 mills for lake shipments, and 3.91 mills for Mississippi River shipments. These costs indicate the need, according to Mr. Cornish, of developing further inland waterways so that the agricultural districts of the great Middle West may be able to compete with the low rates from the Atlantic and Pacific Coasts *via* the Panama Canal. Eventually, the Great Valley will be served by 5 000 miles of trunk waterways, extending from Pittsburgh, Pa., to Kansas City, Mo., and from New Orleans, La., to Chicago, Ill., and St. Paul, Minn. Then, "the relative economy of transportation by railroads *vs.* inland waterways must inevitably be settled by the results of actual operations with modern equipment upon modern waterways."

A General Inquiry.—Interest in waterways, according to Mr. Cornish, seems to culminate about every twenty years. For example, just about two decades ago saw the construction of both the Panama Canal and the New York Barge Canal. Even now, an effort is being made to rectify the mistake of constructing the Barge Canal to such a shallow depth, and the Federal Government is being urged to convert it into a ship canal. The conspicuous success of the Panama Canal has encouraged public opinion in the Middle West to demand the improvement of the Mississippi, in order to equalize for themselves the benefits of water transportation.

As with all other similar projects, the Illinois Waterway has been subject to opposition by numerous strong interests. In this controversy:

* Asst. Chf. Engr., Div. of Waterways, State of Illinois, Chicago, Ill.

"The printed and spoken opposition to the development of waterways for transportation purposes is in the main from two classes, *viz.*, railroad officials or interests and professional economists. The arguments of the railroad class are naturally biased by their concern as to the possible effect water transportation might have on their income and net earnings. Both classes are deeply perturbed at what they call the economically unsound and commercially unfair policy of developing waterways at public expense, and usually point out some particular waterway as a horrible example because of its small tonnage as compared with the total annual expenditures charged against said waterway."

To generalize from isolated examples is obviously unfair. Instead, it is necessary to consider the large problem in its entirety, as to both railroads and waterways alike.

"Railroads are, and probably always will be, our principal agencies of transportation," stated Mr. Cornish, "but the rapidly increasing demand for transportation coupled with the periods of rail traffic congestion and demoralization during past years" are reasons enough for inquiring into the whole question.

Probable Transportation Demands by 1950.—To project present tendencies so far in advance, Mr. Cornish admitted, is a difficult proposition. He made the most reasonable assumption possible—that the trend during the past forty years will continue for twenty-five years more.

As an aid in his calculation he took published reports from official sources, mostly the Interstate Commerce Commission. A few of his results are of interest: The future population of the United States is indicated as 150 000 000; the annual freight traffic should reach 870 000 000 000 ton-miles; to care for this great increase in traffic, about 60 000 miles of additional main tracks and 80 000 miles of additional yard and siding tracks will be needed; each freight car will travel 12 200 miles per annum, with an average load of 23 tons; this will mean the construction of about 57 000 000 tons of additional car capacity at a cost of almost $2 500 000 000; and a similar sum will have to be expended for locomotives.

Cost of Future Plans and Equipment.—All this great added demand for transportation will require future expenditures in trackage and equipment. From the best information available, Mr. Cornish evolves the sum of $60 000 and $40 000 per mile, respectively, as the cost of construction for additional main-line and yard and siding tracks. Other items, such as new buildings, repairs, equipment, etc., were impossible to guess and, hence, their cost is an estimate pure and simple. Based on these considerations and others given in more detail by Mr. Cornish the probable cost of additional railroad trackage, equipment, etc., between 1925 and 1950, for freight traffic alone, will be about as follows:

"Main tracks	50 000 miles	@	$60 000	$3 000 000 000
Yard and siding track	70 000 miles	@	$40 000	2 800 000 000
Freight car capacity	57 000 000 tons	@	$ 40	2 280 000 000
Locomotive tractive power	862 000 tons	@	$ 2 500	2 155 000 000
Buildings, miscellaneous equipment, etc.				765 000 000
Total				$11 000 000 000"

All these estimates of cost, capacity, and efficiency may then be combined. For example, the track construction will cost 3.02 cents per ton-mile of freight capacity; the expense for additional cars will amount to about 7.5 mills per ton-mile; that for additional locomotives will be 6.9 mills; and, finally, the cost of buildings, etc., will reach about 2.5 mills per ton-mile of traffic. Summing these various costs gives an amount of 4.7 cents per ton-mile of freight capacity which will be the probable unit cost of providing additional railroad facilities to handle adequately the increase in freight ton-mileage expected during the next twenty-five years. This cost, then, may be used as the basis of comparison with similar costs for inland waterway transportation.

Waterway Capacities, Mississippi Valley System.—Definite extensions of the Mississippi Valley System are now authorized, which, when completed, will link Pittsburgh and Kansas City in one direction, and New Orleans with St. Paul, Minneapolis, and Chicago, in the other direction. Taking into consideration the channel and lock dimensions in each case, Mr. Cornish shows that the annual capacity required by 1950 will be 60 000 000 000 ton-miles for this entire system.

Based on the present traffic within the Mississippi Valley, and a reasonable allowance for increase within the next twenty-five years, the additional traffic on railroads may amount to 120 000 000 000 ton-miles. Assuming that the waterway system could take care of one-third of this, or 40 000 000 000 ton-miles, this would be equivalent to a water haul of about 60 000 000 000 ton-miles. This, then, would seem to be a rough check on this estimate.

Looking at it from another angle, it may be shown that the annual increase in traffic on various inland waterways, including the Panama Canal, according to public documents, amounts to 14.4 per cent. Such a rate, projected through a period of twenty-five years, would give a tonnage about thirty-six times as great as that in 1925.

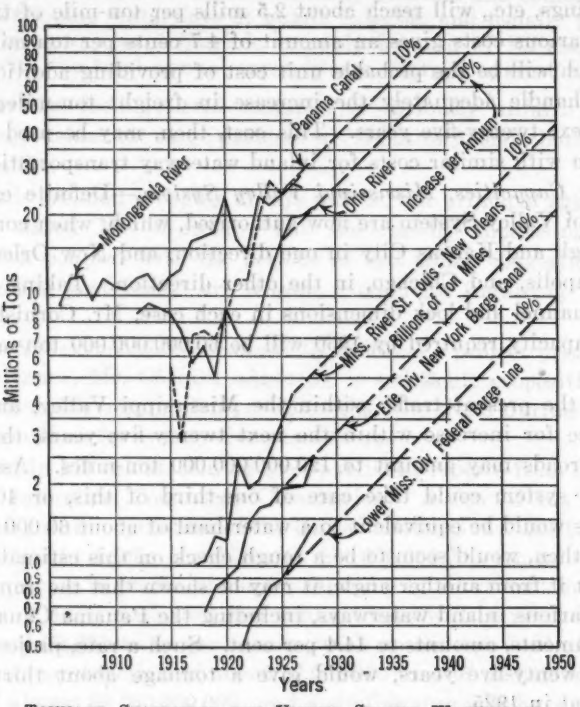
Growing Use of Waterways.—Any delay in utilizing waterways may be accounted for in part by the fact that in many instances, as in the Mississippi, the waterway is still incompletely improved for navigation. With the completion and improvements, even a greater increase can be expected. Even the New York Barge Canal, which has been derided by many, has shown on its main division an annual tonnage increase of 19.4 per cent. If this Canal continues for twenty-five years to increase in tonnage at one-half the rate for 1925, it will have reached its capacity by 1950.

In visualizing the future of inland waterway traffic in the United States, the accompanying graph supplied by Mr. Cornish, will be most instructive. The derivation of all the curves is simple, except that for the Misssissippi River from St. Louis, Mo., to New Orleans, which is in terms of ton-miles, whereas the others are in tons carried. Here, an approximation was required, but this is believed to be on the safe side. The future rate of growth of 10% as shown on this diagram compares then with the 14.4% previously found and is believed to be well on the safe side.

Based on these and other studies as given in detail, Mr. Cornish concludes that:

"The progress in waterway transportation from 1919 to 1925 justifies the assertion that by 1950, the inland waterways of the Mississippi and its tributaries can supply 40 000 000 000 ton-miles of the expected railroad transportation demand of the Mississippi Valley."

This, it will be noted, is equivalent to 60 000 000 000 ton-miles on the river.



TONNAGE STATISTICS FOR UNITED STATES WATERWAYS.

Cost of Waterway Facilities.—For comparison, Mr. Cornish took the cost of the Mississippi Barge Line as operated by the Inland Waterways Corporation. As before, data for this were taken from the records of the Interstate Commerce Commission. Thus, the following cost of equipment is derived:

Item.	Normal capacity, in ton-miles.	Unit cost, in mills.	Total cost.
Terminals and harbor equipment	1 000 000 000	3.00	$3 000 000
Towboats	900 000 000	1.9	1 710 000
Barges	900 000 000	3.0	2 700 000
Self-propelled barges	100 000 000	5.9	590 000
Total	1 000 000 000	8.0	$8 000 000

To this unit cost of 8 mills must be added the further expense for completing the Mississippi River System as now authorized by Congress and the State of Illinois. This total charge of $150 000 000 is equivalent to an amount of 2½ mills per ton-mile for the 60 000 000 000 ton-miles anticipated.

From these figures Mr. Cornish deduces that in 1950 the water transportation on these main inland routes will be at a cost of about 1 cent per ton-mile.

Expense of Freight Transportation.—As common carriers, railroads are subject, with respect to their rates, to approval by the Interstate Commerce Commission. A common carrier for inland waterways, such as the Mississippi Barge Line, is likewise subject to the control of rates. This is true because of the necessity of operating in conjunction with railroads. Traffic on inland waterways without recourse to rail connections would be entirely free from Commission control as to rates.

Because of this freedom from certain expenses of a private line of common carriers, this Government Barge Line can only show the cost of operating towboats, barges, and terminals. As far as the privately owned line is concerned, Mr. Cornish shows, the fixed charges of taxes and interest would so seriously handicap it that it could not survive. However, there is a probability that the item of wharf labor and fuel will show, in the future, a gratifying reduction, which may greatly affect the economy of this system.

With respect to private carriers, there is no question of the economy attained. The experience of great corporations which have availed themselves of the possibilities, demonstrate its great usefulness.

The same may possibly be true of the contract carrier. Thus, Mr. Cornish believes,

"A towboat provides a very attractive and comfortable home for an entire family as well as its means of livelihood. There are many such on the rivers to-day, and their number will increase rapidly as commerce develops."

Economic Advantage of Inland Waterway Transportation.—A differential between rates of railroads and waterways has been set by the Interstate Commerce Commission as 20 per cent. At 11 mills per ton-mile this saving would be 2.2 mills per ton-mile of rail haul, or about 1.5 mills for water haul, and for 60 000 000 000 ton-miles of traffic by 1950, the total saving would aggregate about $90 000 000 per annum.

Considering also the capital cost of transportation facilities for 60 000 000 000 ton-miles, the resulting expense for waterways would amount to $600 000 000, whereas for railroads carrying 40 000 000 000 ton-miles, it would be $1 880 000 000. There results a saving in interest at 5¼%, amounting to $73 600 000.

The answer to this question of finances, together with the other matters dwelt upon in detail by Mr. Cornish, he summarized as follows:

1(*a*).—The annual freight transportation demand of the United States by 1950 will be 870 000 000 000 ton-miles, or 470 000 000 000 in excess of 1925.

1(*b*).—Railroad renewals and increased operating efficiency may provide for an increase of 240 000 000 000 ton-miles.

1(*c*).—Additional transportation facilities must be provided for about 230 000 000 000 ton-miles.

2.—Additional railroad facilities for 230 000 000 000 ton-miles will cost about $11 000 000 000, or 4.7 cents per ton-mile of practical ton-mile capacity.

3(*a*).—Additional freight demand of the Mississippi Valley by 1950 will be 120 000 000 000 ton-miles, 60 000 000 000 of which will require additional transportation facilities.

3(*b*).—The Mississippi Valley Inland Waterway System, when completed, will provide an improved right of way sufficient to accommodate more than 200 000 000 000 ton-miles of freight traffic, if it were available.

3(*c*).—The growth of waterway traffic on the Mississippi System between 1919 and 1928 has exceeded 15% annual increase, and, if continued at a 10% annual increase, with new completed waterways added, will produce 60 000 000 000 ton-miles per annum by 1950, or the equivalent of 40 000 000 000 ton-miles of railroad traffic.

4.—The cost of completing present approved project waterways and providing transportation facilities thereon at 1 cent per ton-mile of traffic expectancy will be about $600 000 000 for 60 000 000 000 ton-miles capacity of floating plant and necessary terminals.

5.—The economic advantage of completing and utilizing the Mississippi Valley Inland Waterway System by 1950 will amount to a minimum of $160 000 000 per annum.

WATER TRANSPORTATION WITH PARTICULAR REFERENCE TO TERMINALS

By Rufus W. Putnam,* M. Am. Soc. C. E.

Limiting himself solely to the question of freight transportation, Mr. Putnam stated that this was only a means to an end:

"The immediate objective is the movement of products of one region which are in excess of local needs to localities that consume more than they produce."

Developing this thought still further, toward the ultimate objective, he asserted that:

"Transportation permits the production of raw materials of industry in regions too sparsely populated to consume any quantity of the products of industry; it allows the development of industrial centers where labor supplies are ample and living conditions comparatively good; it permits the production of great quantities of food supplies where conditions favor their growth; in other words, it has broken the barriers within which the laws of supply and demand have operated and removed them to points which grow more remote from year to year."

Such a system affects consumers as well as producers and utterly controls the resulting economic structure. It has social as well as political consequences and, therefore, the problem demands a broad treatment of its fundamental elements.

Types of Transportation.—Air transport was briefly discussed by Mr. Putnam. Its routes are easily and cheaply maintained but, in terms of ton-mile hours, the carriers are most expensive to build and operate and the ports most costly to build. Thus, "the only advantage of air transport being speed, its field of usefulness and economy resolves itself into the movement of goods where time of delivery is a controlling factor."

* Pres., The Maritime Eng. Corporation, Chicago, Ill.

Rail transport, on the other hand, is handicapped by costly lines and terminals, but has cheap rolling stock, relatively, and flexibility of route. There results a "more universal utility" and its field "covers the transportation of all classes of goods over all distances, from short to long."

Use of trucks, by comparison, avoids a large item of cost, that of terminal charges. Since these are "a proportionally greater part of the total transport cost in a short-haul operation, the truck is ostensibly a short-haul carrier. On account of its flexibility it is adaptable to the movement of a wide variety of goods."

Water transport varies largely according to the type of carrier used. Thus, overseas traffic uses ships exclusively, whereas inland waterways may be forced to depend on barges or canal craft.

"Ships cost more to build per unit of cargo carrying capacity than do rail carriers, but are considerably cheaper to operate; barges and other river craft are generally cheaper to build as well as cheaper to operate than rail carriers."

The big item of expense, however, is for water terminals. Not only are these more expensive to build, *per se,* but they require in addition accommodation for land carriers, as well as channels, piers, and bulkheads for water carriers. As to economy they therefore require individual study for each case.

Lake Terminals.—For commerce on the Great Lakes one form of terminal simply transfers goods between land and water carriers. As compared with this "interchange terminal", another type serves adjacent commercial plants with incoming or outgoing freight and is usually called an "industrial terminal."

Interchange terminals which form one step in the middle of a long haul are further classed as terminals for through traffic. For them, local demands have little consideration; that is, they are independent. Again, the goods may be of near-by origin or destination, and this fact largely affects the location and planning. More often both classes are to be considered and a compromise is inevitable.

Terminal Development.—The usual history of terminals has been that as they have created business, civic development has crowded them out to less congested quarters. Each location, then, had to stand on its own feet and "was considered separately as more or less of a local problem and with little regard to its significance from a National point of view."

A more rational plan, now in vogue, allows one terminal to do the work of several old ones, but does it better and more cheaply.

The Federal Government naturally is concerned with routes and channels, leaving to local interests the details of the ports. This accounts, suggests Mr. Putnam, for some of the confusing results—duplication of facilities and decentralization.

Regional Planning.—Artificial boundaries or jurisdictions are responsible for unfortunate local attitudes:

"It is therefore desirable that any treatment given the question of terminal facilities should first have the attention of a National point of view by the Federal Government, and be considered from a regional point of view as regards matters of location and design by some body with more than a strictly local idea of the situation."

As applied to water terminals, regional planning lacks recognized standards as to plans, arrangement, capacities, and the many other essential facilities. Results achieved in Europe and America have given a few guides, thinks Mr. Putnam.

Basic Factors.—At the outset, three determinants are apparent,

"Physical features of the terminal region; load characteristics, or traffic; and characteristics of water carriers and routes. The design of shore accommodations, their arrangement, size, and capacity depend upon these factors to a very great extent."

Even distance from the open sea or limited quarters for a harbor are not insuperable difficulties. The site, however, does require:

"In the first instance protection from the open seas and obstructive currents; secondly, ample area of sufficient depth for the anchorage of vessels; thirdly, area to permit the construction of shore facilities, such as piers, warehouses, storage yards, railroad yards, and rail and street connections. The location selected should be capable of expansion by the addition of units for many years in the future."

* * * * * *

"Free, unrestricted, and direct interchange of freight between all kinds of land and water carriers should be provided for at all the major terminal developments within a port."

Economies of Transportation.—Oftentimes, Mr. Putnam emphasized, there is a tendency to disregard a major detail—over-all costs. Methods of allocating division of charges may serve to mask real cases of excessive cost.

Whether the facility falls into the classification of routes, carriers, or terminals, the details of fixed charges, maintenance, and operating costs are important. Indirect costs also need attention, as "where a railroad or a waterway imposes a burden in the way of interruption of other means of transportation, bridge, or viaduct expense, and, in some cases, a degree of nuisance."

It is true, according to Mr. Putnam, over-all costs do vary greatly with different kinds of transportation, as, for example, between the right-of-way burdens of waterways and railroads; but

"The mere fact that a part of the costs in some instances is concealed in tax assessments should not alter the treatment of the subject, any more than should the fact that low rates for land haul in some localities have to be made up by the carriers at the expense of other localities. The expense exists, and some one has to carry it, and speaking broadly, it is an economic drain on the country as a whole, if it cannot be more specifically isolated and applied."

Benefits of a Transportation Facility.—To extend known costs and advantages of a specific route to one projected, is at best risky:

"A pretty safe conclusion to follow, however, is that where an investigation shows that a new route or a different method of transportation shows a decided differential in over-all costs in its favor, and the area to be served is capable of producing or consuming in excess of its consumption or production, commerce will follow in the wake of the provision of the requisite facilities."

Economics of Water Terminals.—Terminal costs are complicated because the Government may provide the protection works; the municipality, the piers;

and the carrier only has to charge for operating costs. This results in spreading the over-all expenses, as the benefits also are extended, beyond the immediate users.

Issuing a note of warning, Mr. Putnam concluded as follows:

"Many a locality has seen a neighboring port city flourish, has come to the conclusion that it may do likewise, although it has neither the local population required nor an independent hinterland to supply the requisite flow of traffic; has bonded itself heavily for port facilities; has expended large sums for soliciting and holding trade; and has nothing more to show than perhaps a small local boom in real estate and business which is not at all comparable to the expense to which it has gone.

"The time has come where a revaluation should take place of the transportation situation in several sections of the country, where regional if not National economics should govern future expenditures for water terminal developments, to the end that the energy and resources available may be devoted to obtaining the service necessary with the elimination of as much duplication and useless expense as possible."

FEDERAL WATERWAY DEVELOPMENT

By Lt.-Col. George R. Spalding,* U. S. A.

In discussing the program and work of Federal waterway development, Colonel Spalding made it perfectly clear that he was expressing only his own personal views. In this immense work, various objects are in view; he outlined a few of them as follows:

"The interest of the Federal Government in waterways is a National, not a local, interest. It is an interest which lies among the very fundamentals of National unity.

"The immediate objective of this interest is to preserve and protect these precious rights of way to the sea against all encroachments and restrictions which may interfere with their free use and ultimate development.

"The ultimate objective is not the improvement of waterways alone, but rather the securing to all sections of our country the cheapest and most unrestricted transportation facilities for commerce between and among the States and to the sea and the markets of the world, which a bold, imaginative, and progressive engineering can devise and a broad National economic viewpoint can justify."

Harbor Program.—In developing harbors, the National viewpoint has evidently been kept uppermost, and the larger seaports have not received a disproportionate or exclusive share of attention.

The development along the Texas Coast is a case in point. As long as forty years ago, according to Colonel Spalding, Galveston was selected as the logical point along the coast for a deep-water harbor. As a result of this and subsequent works, its channels now serve not only seaports in the immediate vicinity but also the Houston Ship Canal. Inland transportation and waterborne commerce have been developed so that:

"A fine combination of good north and south railroads, fine terminals, ample harbor facilities, and a broad easy outlet to the sea has brought about a saving in the freight bill of the West which amounts each year to one-half the total cost of the Federal improvement."

* Lt.-Col., Corps of Engrs., U. S. A., Louisville, Ky.

Inland Waterways.—Because little harbor development had been undertaken prior to the Civil War, the development under Federal auspices, once it was begun, was unhampered by existing construction.

This was far from true with respect to inland waterways. Everywhere local improvements were found, many of them already antedated. In size, depth, capacity, and arrangement, they did not serve the newer needs for economy. Although many of these developments were on minor, or side, streams, nevertheless they did exert a harmful influence in preventing a true conception of what real waterways should be.

As an example of National development on a broad scale, Colonel Spalding instanced the Great Lakes-Ohio-Mississippi route. Although it is not 100% waterways, yet in the wider sense it provides a through route of "National transportation".

He showed how ore was handled economically from the mines of Northern Minnesota, by way of immense lake ore carriers, to Northern Ohio; thence by rail to the steel district; the finished product sent by barge down the Ohio and Mississippi Rivers to or toward the coast; and, finally, distributed by ship or rail to the consumer.

The results from the standpoint of economy are encouraging. Thus:

"The Great Lakes section of this route is returning to the country a dividend in freight savings of 100% per year. The Ohio-Mississippi Section is not yet on a paying basis. The investment cost and the operating costs are both much higher for the river than for the lake channels, and tonnage is less.

"Nevertheless the constantly growing tonnage on the river section, with the river improvements not yet completed, and the growing, serious interest being taken in the possibilities of the route by our largest industrial and public utility companies promise that before very long we will be 'out of the red'."

Adequacy and Expansion.—The basic thought behind all the waterway development was expressed by Colonel Spalding as "the principle of *adequacy* from the first with *room* for expansion to meet the ever-increasing need for economies in the movement of commodities in bulk."

Whether it be considered from the standpoint of channel dimensions, terminal and anchorage capacity, or ample room for expansion, Galveston Bay is adequate in every sense and provides opportunity for further great development. Similarly, with the Great Lakes, lock dimensions and clearances, channel depth, and permanent constructions, all have been planned to provide full capacity for future needs.

The Ohio-Mississippi Plan.—As contrasted with these other improvements the plans for developing the Mississippi and Ohio Rivers have recognized very definite limitations. For example, the draft may be only 8½ ft. Thus, the economical cargo carrier is not a single vessel, but rather a fleet of shallow barges with a light-draft towboat, the whole designed to act, as nearly as possible, with the simplicity of a single vessel.

The advantage of towing in an open river, especially down stream as in the Lower Ohio, has led to the adoption as far as possible of movable rather than fixed dams. As the river rises sufficiently the dams are lowered, and free navigation is permitted. As a result during certain seasons of the year, tows amounting to 25 000 tons, and, in dimensions, 720 by 250 ft., are possible.

At other points—notably Louisville, Ky.—navigation is restricted to using the locks at all times. Thus, all the operation is aimed:

"To keep the river navigable for the low water months, without spoiling it for the high water months.

"We are doing this by building a system of locks and movable dams which at high water are entirely submerged. As the river falls and supply from the tributaries decreases, we raise the wickets, thus restricting the cross-section available for flow and creating a channel reservoir.

"These are shallow reservoirs, yes, but reservoirs located where they will do the most good to navigation and incidentally the most good also to the water supply plants, the manufacturing plants, and the public utility steam plants of the cities along the main stream."

Reservoirs.—Some of these pools created by the dams are of great service to private corporations. Again, one of the first interests to be affected by a reduction in level, may be the public water supply.

A great help to the operation of such channel reservoirs, remarked Colonel Spalding, lay in the private storage along the tributaries:

"* * * so long as they feed a greater quantity of water to us, when we need it, than we would get without them.

"All in all we are pretty well convinced that with a given dollar of river and harbor funds we can do more for navigation and commerce by building our first reservoirs where they will serve a double purpose.

"A foot or two of extra depth in a pool, here and there, gives us a very useful reserve to help out lower pools when necessary, and when not necessary, the deeper water of the reserve pool gives freer navigation.

"Sometime in the future perhaps a storage reservoir or two on some of our main tributaries built perhaps in co-operation with power interests will give us a larger low-water flow and more dependable channels at the upper limits of pools. We already notice good effects from some of the hydro-electric plants on the tributaries."

Channel Maintenance.—Fortunately, the Lower Mississippi is free from navigation troubles through much of the year. It is mainly after a period of high water that reefs and bars build up across the channel.

If the demands of navigation were less pressing, the river itself could be depended upon to open up a new channel. As a matter of economy, however, Colonel Spalding explained, great suction dredges are used to start the process by cutting a narrow trench through the obstruction and allowing the river to do the rest.

Even training works of a minor character have been used to assist in stabilizing the channel. Care has been taken not to use such large works that they might impede navigation during the high-water stages.

DISCUSSION

ECONOMICS OF WATERWAYS AND RAILWAYS

In commenting on Mr. Cornish's paper, Colonel Spalding felt that the allowance of 5 mills for river equipment of barges and towboats was an under-estimate. His own figure was more nearly 1 cent per ton-mile. In

this computation, he used a lower "load factor" than that of the Federal Barge Line. This is true because "as equipment increases to meet peak demands—as it must, if we are to have real service on the rivers—the load and use factors must fall somewhat and the investment factor must increase correspondingly."

As to the tonnage increase on the Ohio, Colonel Spalding corroborated the figures given by Mr. Cornish for 1915-25. This increase continued through the year 1926 and then fell abruptly. The fact is that no new equipment was introduced during 1927 and 1928. However, the lack is being remedied and already this year (1929) three new fleets have appeared on the Ohio, while the Federal Barge Line is also adding equipment, so that the tonnage increase should continue during the next year or two.

Future Prospects.—In summarizing the results of his study on this important problem, Colonel Spalding stated that:

"From a National viewpoint, the future value of the rights of way offered by our great trunk line rivers, depends primarily on their adaptability to a character of improvement which will admit of a very cheap movement of great bulk cargoes.

"The model experiments and actual river tests of the so-called 'Towboat Board', of which I am privileged to be a member, show conclusively that light-draft river navigation can move most economically in large tows of great length-to-beam ratio; that in down-stream movements where natural physical conditions of the river preclude tows of desirable length, the tonnage capacity per towboat necessary to insure a cheap through rate may be securable by increased width.

"In the study of any proposed light-draft inland waterway development or improvement, we must give first consideration to the economic composition of the tow for long-haul trade in the commodity most likely to be handled and no plan should be recommended which will not permit of a reasonable development of the trade and of the improvement along economic lines."

TERMINAL OPERATIONS ON FEDERAL BARGE LINE

By W. F. Schulz,* M. Am. Soc. C. E.

While ostensibly the discussion by Mr. Schulz dealt with the general question of rail and waterway transportation, actually it was a complete treatment of one special phase of this great topic, namely, the principles underlying the operation of terminals on the Federal Barge Line and the lessons to be drawn from past experience.

He quoted General Ashburn's figures to show that almost 40 cents out of every dollar of income was used in terminal operations and maintenance. Although the operation of the line itself is quite economical, this excessive terminal charge goes far to nullify any savings effected by the cheap haul.

Municipally Owned Terminals.—The Barge Line, like a railroad, is limited in capacity by the ability of its terminals to handle freight expeditiously. Quite generally, these river terminals are owned by the cities in which they

* Memphis, Tenn.

are located. Mr. Schulz explained the reason for this. In effect, it is to protect the cities themselves. If, and when, the Government elects to sell its line, it would be very awkward if the terminal facilities were likewise sold to a private organization. Private lines are being encouraged to establish themselves, but this can only be done if assurance is given of use of common terminal facilities. A city must assure itself of such control, in the opinion of Mr. Schulz, "if it is to retain the full ultimate advantages from cheaper river transportation".

Again, a city has to equip its terminals so as to handle freight to and from points at some distance from the river. Many of the terminal costs are fixed, irrespective of the amount or kind of traffic handled; on the other hand, the Federal Barge Line, or any other user, for that matter, pays the city in proportion to the amount of freight handled. "Therefore it behooves each city to attract all possible tonnage through its terminal to increase the revenue from which its fixed charges must be met."

Freight Packages.—Terminals must be planned in anticipation of the form of freight which will be offered. As Mr. Schulz put it,

"Failure to give proper consideration to this question of packages has probably produced more inefficient terminals or more inefficient elements in terminals than any other one thing. In other words mistakes have been made through the failure to appreciate that the Federal Barge Line transportation is more nearly an adaptation of railroad traffic to the water than an adaptation of oceanic traffic to rivers."

In railroad experience the matter of handling freight has developed from the requirements of the commodities in certain forms or packages. In a similar manner the style of packing has been evolved from the demands of the carrier that the minimum of damage in transit may be expected.

Ocean shipments, on the other hand, have an entirely different object in view. The packing must be heavier and stronger to withstand the increased hard usage. Further, the loading cannot be effected practically on one level as with a railroad; instead various cranes, gangways, and other aids have to be brought into use.

Peculiarities of a River Terminal.—The Barge Line terminal has to partake of some of the characteristics of both the railroad freight station and the ocean pier. For example, only in a limited way can it use cranes to advantage, and this with respect to commodities such as are easily shipped in flat cars. As to freight handled in box cars, "the nearer a river terminal can approach the handling of packages employed in a railroad terminal, the more generally efficient and economical will be the result." Mr. Schulz' experience on the Barge Line is that about 75% of the material is of the kind suited for a box car and has its origin or destination at some distance from the river.

One difficulty with a river terminal is in the difference or variability of elevation; thus, at one point on the Mississippi, the water stage has a variation of 10 ft., whereas at another point it is fully 60 ft.

Still another and equally great difficulty is in the horizontal movement required between low and high water, which may amount to 500 ft. or even in extreme cases to 1 400 ft., as at Memphis, Tenn. Obviously, the ordinary

vertical landing stage used for a wharf at sea level will not solve the difficulty on the Mississippi. The requirements of protection from the weather have been best solved by using a covered conveyor, operating between the barge and the terminal above.

Typical Terminal and Its Operation.—The results of these various demands for a river terminal were illustrated by Mr. Schulz in describing what has proved in operation to be the most desirable form. At the river's edge will be a steel wharf barge and connecting it with the terminal above will be an escalator. The upper terminal will provide the full use of railroad facilities as determined by the local rail conditions.

Doors in the wharf barge correspond in position to similar entrances to the river barges, so that when the two are moored together there is direct access *via* the wharf barge to the terminal above. Thus, four-wheeled trailer trucks are loaded and placed on the escalator (without an attendant) and when they arrive at the top are segregated into "trains", in which form they are hauled to the proper destination, as to the city freight house, to the warehouse, or direct to the railroad cars. At the same time, empty trucks are going down a second escalator for further loading.

This typical operation of package terminals has been evolved, Mr. Schulz explained:

"Virtually by the process of elimination, from all the various types and schemes of handling which were tried in the early days of the Barge Line operation. It is used at the smaller ports where there is a substantial amount of the tonnage with either its origin or destination in the port city."

Interchange Terminals.—A different problem confronts a terminal which handles mainly freight bound to or from more distant points. This, in effect, is practically simply a transfer from barge to railroad, or *vice versa*, and the solution is distinctly different from that for the previous type.

A railroad incline from the yard above and extending down to below low-water line, is equipped with a wedge-shaped structure known as a cradle and several car-floats. The cradle serves as an intermediate rail connection between the fixed incline and the movable floats. Wharf barges are also used; their function is to provide a mooring alongside the car-float whereby direct access is obtained from the river barge to the railroad cars.

Whatever the river stage, this type of terminal operates successfully. It demands a minimum of distance for trucking between the barge and the car. Actually, according to Mr. Schulz, it "gives the lowest per ton handling cost of any of those developed, but cannot, of course, be used economically in places where the interchange tonnage is small."

Special Terminals.—Cranes have been used to a limited extent, but for special products, as, for example, steel. They are not satisfactory for ordinary packages and, of course, cannot be used for products affected by the weather.

Still different terminals are required on the Ohio River, as the Federal Barge Line is precluded from operating there. The special commodities handled dictate the details of the terminals.

Commodities as Freight.—Only to a limited extent is grain handled on the Barge Line and this is for export through the Port of New Orleans. Addi-

tional elevators and other grain-handling facilities are being considered for the upper river. As to other merchandise,

"The principal commodities handled northbound out of New Orleans during the year 1928 are as follows: Rice, coffee, sisal, bauxite ore, salt, sugar, syrup, nails and wire, bars, sheets and structural steel, burlap bags and bagging, canned goods, prepared roofing, merchandise, miscellaneous freight.

"New Orleans receives from the Barge Line grain, agricultural implements, cotton, ore concentrates, canned goods, roofing, syrups, tobacco, merchandise, bars, sheets and structural steel, rice, coal, rails, cotton, ties, pig iron, lumber, and cement.

"The principal down-stream tonnage through the Northern terminals is grain and through the Southern terminals is cotton and tobacco, while the principal up-stream tonnage is bauxite ore, sugar, sisal, burlap, coffee, and canned goods."

Cost.—Terminal expenses comprise maintenance, depreciation, and tolls, but do not include switching and fixed charges. They vary considerably; for example, between 60 cents at Birmingport and 83 cents at Cairo, Ill., to as high as $1.60 at St. Louis, Mo. At other points on the Barge Canal, the costs are more uniform and average about $1.20.

The terminals themselves vary considerably in size and cost. The lower and upper limits are $200 000 and $2 000 000, respectively.

The Future.—During its first years, Mr. Schulz admitted, the Barge Line was on trial. Conditions, however, are different now; he is fully convinced:

"That this period of trial has passed and this type and character of transportation has proven both its immediate and ultimate worth and that it is here to stay with ever-increasing volume and importance. This type of service is not a thing isolated or apart from the industry and the commerce of the remainder of the country. Nor was it created to hamper in any way the excellent and expeditious service offered by the rail carriers. The Barge Line is naturally a slower service and for this reason its rates on general merchandise are about 20% lower than the all-rail rates."

CITY PLANNING DIVISION

JULY 11, 1929—9:55 A. M. TO 12:50 P. M.

In the absence of Chairman C. E. Grunsky, W. W. DeBerard, Member of the Executive Committee, introduced the first speaker.

COUNTY AND REGIONAL PLANNING

By E. A. Howard,* Esq.

The paper was prefaced by a definition of regional planning, as follows:

"Regional planning is simply the common sense preparation of carefully designed plans, and the application of such plans to an area of considerable size in order to promote the economic, social, and general welfare of the region. County planning may be identical with or a part of regional planning."

Mr. Howard declared that regional planning developed from the city planning movement that began shortly after 1900.

General Comparisons.—Whereas city planning problems are the result of disorderly crowding of humans within a city, regional planning problems are the result of disorderly development of cities and villages crowding against each other.

The fundamental procedure involved is substantially the same, except on a different scale, because:

"Crowding is as irksome to municipalities as it is to individuals and a spirit of irritation and resentment often arises which prevents co-operation in the preparation and execution of plans for public improvements. In other instances cities and villages are so engrossed with their own problems that little or no thought is given to municipal improvements planned by their neighbors, and even if such matters were given consideration by any one municipality, it is very doubtful if the plans proposed would be adopted by the other cities and villages of the region."

Genuine co-operation is needed, especially in the planning of numerous unincorporated areas outside of cities and villages. Outstanding examples of regional planning bodies in the United States are given by the author as follows:

"The Regional Plan of New York and Its Environs, extending its influence not only over cities and counties, but over parts of three States.

"The Tri-State Federation of Philadelphia, likewise extending into three States.

"The Niagara Frontier Planning Association in the vicinity of Buffalo, Tonawanda, and Niagara.

* Superv. Engr., Milwaukee County Regional Planning Dept., Milwaukee, Wis.

"The Chicago Regional Planning Association, active within a fifty-mile radius of the Loop in Chicago, covering parts of Wisconsin, Illinois, and Indiana.
"The Greater Kansas City Regional Planning Association, recently organized by six counties in the vicinity of Kansas City.
"The Los Angeles County Regional Planning Department.
"The Milwaukee County Regional Planning Department."

The possibilities of regional planning are almost unlimited. In the opinion of Mr. Howard:

"A few of the more important undertakings in which regional planning may be of value, either directly or in an advisory or co-operative capacity, for the development of the metropolitan area, are:
"A water system.
"A platting system.
"A highway system, including a system of major thoroughfares.
"A park and parkway system.
"A system of recreational centers and playgrounds.
"A transportation system.
"Zoning.
"The co-ordination of these and other similar activities."

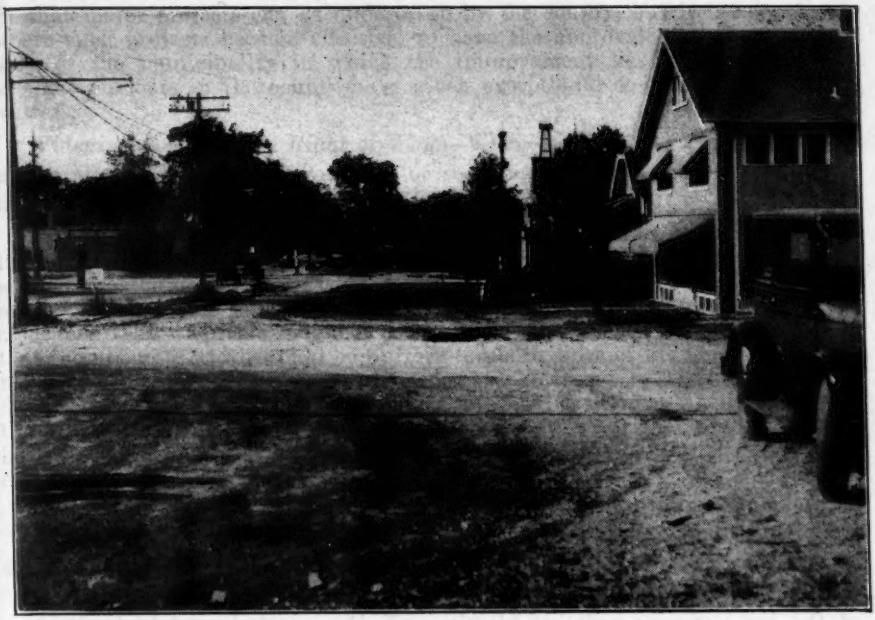
Several agencies within a region may be actively interested, he stated, in regional planning. The Regional Planning Department may be merely an advisory body, co-ordinating the other agencies, or it may be an integral part of the county government, with powers to create plans and to supervise their execution as well.

Regional Planning in Milwaukee County, Wisconsin.—The work in this county received its first impetus in 1908 with the creation of the Milwaukee County Park Commission. This was one of the first regional planning bodies in the United States. The work done by this Commission was supplemented, somewhat later, by the creation of the Milwaukee Metropolitan Sewerage Commission which, according to Mr. Howard,

"Developed a complete system of sanitary sewers and a disposal plant to take care of the sanitary sewage in that area within the county lying within the water-shed of the Milwaukee, Menominee, and Kinnickinnic Rivers. The sewage from each city, town, or village within the area, is carried to one central disposal plant, and the cost of treating is charged back *pro rata* to the various municipalities, according to the amount of sewage treated from each. This is an illustration of a real regional project."

Nevertheless, some unorganized development in non-incorporated areas located between cities brought about the organization of a Regional Planning Department in 1924. As conceived at present, this Department is organized partly as a Planning Department and partly as a Public Works Department. Its program includes: (1) The development of a proposed county parkway system; (2) regional platting; (3) zoning within the county; (4) highway widening; (5) park engineering; (6) landscape work for county institutions, etc.

The Department concentrates on work to be done outside the corporate limits of cities and villages and accomplishes co-ordination by co-operating with various local agencies that exist for similar purposes in the larger centers.



BUILDINGS ON HOWELL AVENUE, MILWAUKEE, WIS., SET BACK TO ALLOW AMPLE ROOM FOR FUTURE STREET WIDENING.

BUILDINGS ON FOND DU LAC AVENUE, MILWAUKEE, WIS., SET BACK UNDER THE HIGHWAY RIGHT-OF-WAY WIDENING ORDINANCE.

"One feature of all county planning laws in Wisconsin", Mr. Howard states, "is that major projects can be undertaken by the county, but it is necessary, before such projects become effective, to have the approval of the governing body of the municipality in which the improvement lies. The town and city governments in the county have given exceptional co-operation in these matters."

Widening the Highway Right of Way.—When the Regional Planning Committee attempted to make provision for securing added widths on certain of the main highways, according to Mr. Howard,

"It was found that the average subdivider when asked to dedicate a width in excess of the existing width did not object so much to dedicating the land asked for as he did to the lack of assurance of uniformity in dedication. If one owner dedicated land for a width of street of 110 or 120 ft., he wanted assurance that when his neighbor platted, the same width would prevail, so that the ultimate width would be uniform on both sides of his holdings. This request on the part of the realtor seemed reasonable, and as a result a bill was drafted, and passed by the 1925 Session of the Legislature, authorizing the County Board of Milwaukee County, with the approval of the individual town boards of the county, to establish a width in excess of that actually and presently in use."

The result has been very successful. In effect, the ordinance is merely "a declaration of intention on the part of the county to provide ultimately a street or highway of the width specified."

There are two ways to insure compliance with the law respecting predetermined highway widths: (1) To withhold building permits; and (2) to withhold approval, by the County Board, of the subdivision plat. Commenting on the general effect of the law, Mr. Howard stated:

"To date, property owners have dedicated in excess of fifty miles of widened highway on plats of record. By obtaining wide rights of way at the time of platting, and by keeping buildings back from the street line along narrow rights of way, the taxpayers of Milwaukee County are being saved many thousands of dollars."

In general, land is acquired by dedication, except in such instances as those in which it is necessary to pay damages for improvements such as fences, trees, buildings, etc. From experience in Milwaukee County, Mr. Howard estimated that the cost for damages due to existing improvements would be somewhat more than $25 000 per mile.

Laws for County Planning.—Mr. Howard summed up the legislative aspects as follows:

"An outstanding accomplishment of county planning in Milwaukee County is the Zoning Ordinance, adopted by the Board of Supervisors in October, 1927. It is one of the first County Zoning Ordinances to be adopted in the United States, and its passage followed nearly two years of preparatory work.

"The Wisconsin Enabling Act, at the time of the preparation of the Zoning Ordinance, permitted the establishment of Use Districts only, and by the Zoning Ordinance Milwaukee County has been divided into the following seven classes of Use Districts:

"'A' Residence District.
'B' Residence District.
Local Business District.
Agricultural District.
Commercial and Light Manufacturing District.
Heavy Industrial District.
Unrestricted District.

"The various districts created do not differ greatly from those found in the usual zoning ordinance, except that the creation of an Agricultural District under the zoning ordinance does not mean that this district will be limited to agricultural use, and should not be confused with the policy of some city planners in attempting to establish permanent agricultural belts around or surrounding city development."

The idea is merely to restrict the use of this Agricultural District from industrial development until the city has grown so that further expansion is necessary. Then:

"The Residential Area, through amendment of the Zoning Ordinance, will, from time to time, be extended into the Agricultural District so as to maintain a proper balance of Residential and Local Business Zoning."

Pollution of Streams.—Regional planning departments must make themselves interested in parkway systems, according to Mr. Howard, and as a part of such systems, they must consider regional steps to prevent the pollution of streams along parkways. This is largely helped by preventing the control of lands abutting a stream by private owners. With this in mind:

"Milwaukee County has adopted a tentative eighty-four mile plan of parkway development, and land acquisition and construction are now under way. The County Board has established a definite policy with respect to land acquisition. Land for parks is purchased outright by the County Board and paid for out of general taxes. The County Park System to date consists of some 1 800 acres of land and, in addition, 500 to 600 acres are now under option or are being condemned for park purposes. The County Parkway system, on the other hand, is financed entirely through dedications of the land required or by acquisition of the land through an assessment of benefits and damages. To date land for two and one-half miles of the Parkway System has been dedicated along the Menominee River. The necessary right of way for over a mile of Parkway System has been tendered the County on the Root River. The County Park Commission and the County Board now have under consideration the acquisition of five additional miles of parkway by condemnation and an assessment of benefits and damages therefor."

Considerations that affect parkway projects most seriously are the need of educating the public and the fact that a plat, once established, is almost unalterable. The first of these can be solved by illustrating parts of a parkway that has been completed. Since the project in Milwaukee has been undertaken (to quote Mr. Howard), "and it is possible to visualize the appearance of the future system, there has been an increasing demand for parkway construction in other sections of the county."

In conclusion, he states:

"The results of any planning activities are not noticeable immediately; but based upon local experience, it seems safe to say that a county is the logical body for the carrying on of planning activities in those areas beyond the corporate limits of a city or village, since usually all cities, villages, and towns are represented in the county government, and, therefore, under county government better co-operation and better results can be obtained than under any other arrangement of planning control. In a large region it is essential that the function of the regional planning body extend over several counties and then County planning should be a part of the regional plan, supplementing the work being done by the village and city planning bodies of the region."

After the paper was read, the author showed a number of slides illustrating various points mentioned.

DISCUSSION

COUNTY ORGANIZATION FOR REGIONAL PLANNING

By A. J. Rabuck,* Assoc. M. Am. Soc. C. E.

Although there are admittedly some disadvantages in the tying of a regional planning program to a county organization, it has the advantage of simplicity in the matter of adjusting the necessary governmental machinery, according to Mr. Rabuck. It is true that "a major city is more apt to be near the boundary line of a county than near the center" and that, therefore,

"Co-operation would be necessary wherever a planning region extends into several counties, but a great deal of co-operation is necessary in regional planning, under any scheme of organization."

Mr. Rabuck felt that it was a mistake for a regional planning organization to confine its efforts merely to unincorporated areas outside villages and cities. It should undertake to create a master plan, unifying all the individual projected plans within a region. Wisconsin has passed a bill creating a State Director of Regional Planning whose duties will be to co-ordinate the activities of local planning agencies throughout the State.

Effect of Legislation.—The so-called highway right-of-way widening law recently passed by the Wisconsin State Legislature is merely an "Enabling Act", designed to place power in county organizations to adopt major street or highway plans. The effect has been satisfactory and, quoting Mr. Rabuck,

"The remarkable thing about this county highway widening plan is that it has met with public approval and the property owners are voluntarily setting their new buildings back to the new lines. The comprehensiveness of the plan and its official character have won the confidence and co-operation of the public. Mr. Howard was extremely conservative in placing the saving in Milwaukee County at $25 000 per mile. This figure merely represents the cost of widening these highways by condemnation at the present time, and is only a small fraction of what the cost of widening would be in ten or fifteen years from now with a lot of new buildings built to the old street lines."

Mr. Rabuck expressed regret that the Milwaukee County Major Street Plan "does not provide for any of the cities or villages", but stops at political boundary lines. He declared that:

"The County Board has no authority to zone incorporated cities or villages, but all except two incorporated places in the County have their own zoning ordinances. The county ordinance should, in the writer's opinion, be amended, by creating height and area districts in those towns which are rapidly becoming urban in character. New enabling legislation will be necessary for this, unless the County Board can proceed under its newly acquired power of home rule."

Residences in Industrial Districts.—An important item in fixing zones is that residences be excluded from land assigned to industrial districts. To do otherwise, in the opinion of Mr. Rabuck, is to discourage the use of the land as planned, because:

* Asst. City Planning Engr., Board of Public Land Commrs., Milwaukee, Wis.

"Few industries can afford to buy land occupied by houses, for factory purposes. The exclusion of residences from land zoned for industry is desirable from the standpoint of good health and public safety as well as from that of economic industrial development. There is a question as to the legality of thus excluding residences for industrial zones, but Mr. Edward M. Bassett, a leading legal authority on zoning, believes that, if the exclusion of residences from industrial districts is reasonable and not arbitrary, the Courts will uphold it."

Parks and Parkways.—He approved the practice of acquiring land for parkways by condemnation and assessment of benefits and damages. He recommended the same practice as a means of securing larger recreation areas. It does not seem feasible to plan major park improvements by payments from the city funds, as Milwaukee and many other cities do.

"Certainly", said Mr. Rabuck, "under such a policy, the public cannot expect to dedicate lands for recreational purposes.

"The experience in Milwaukee County has demonstrated that comprehensive planning is wise and practical. The chief regret is that a start was not made many years ago."

GENERAL DISCUSSION

Supplementary information concerning planning work at Lincoln, Nebr., was offered by M. I. Evinger, M. Am. Soc. C. E. He stated that, while no city plan had been prepared, a special bill had been passed that established zoning regulations within the area set aside for State buildings and public institutions. This, he hoped, would constitute a step toward a general regional plan.

The next discussor was Charles F. Loweth, Past-President, Am. Soc. C. E., who presented the problem from the railroad point of view. He emphasized the fact that the railroad is as essential in the modern urban development as a residence or industry and yet railroad men often are made to feel that city plans are designed to "wipe the railroad off the map", as being of little or no importance. The railroad companies are quite in sympathy with city planning, according to Mr. Loweth, when it presents them an opportunity of planning their own future developments but "sometimes it looks as if the only possibility the railroad has for expansion is way outside the city, and sometimes outside the County, where we would not be of very much use to the municipality."

Chairman DeBerard expressed agreement with the idea that railroads should be given adequate consideration as an important part of the transportation problem in the city plan. To carry the idea further, he pointed out the relationship between highway and railroad traffic and the importance of giving due weight to grade crossing problems in city plans.

George A. Ricker, M. Am. Soc. C. E., commented on the application of set-back lines to the city plan of Washington, D. C., especially in the district beyond that provided by the original plan developed by L'Enfant. According to Mr. Ricker, until the MacMillan Plan was adopted by Congress, about 1891,

"This great belt of territory outside of the L'Enfant plat was platted and grew up with the most dreadful arrangement of streets; disconnected, no proper extension of thoroughfares and, in general, that area is a terrible problem for the Planning Commission of Washington. * * *

"When the National Park and Planning Commission was established by law some three or four years ago, it was given additional powers, and this matter of street widening and correction of lines, the extension of thoroughfares, and all that sort of thing, was included in the MacMillan Plan, so that now the Committee of the National Park and Planning Commission supervises the extension of streets, the adoption of new plats, the widening of thoroughfares, and the connecting of new with old thoroughfares; but it is a tremendously expensive proposition."

This great cost for improvements in older cities lends extra importance to the ideas outlined by Mr. Howard for making far-sighted preventive plans in newer cities. The set-back idea is embodied in the MacMillan Plan.

THE CITY PLAN OF KENOSHA, WISCONSIN

By W. E. O'Brien,* Esq.

The method of organizing, and the powers invested in, a city planning commission are defined by the laws of the State of Wisconsin. Mr. O'Brien began his paper with references to the statutes in which the process of organizing is outlined. Under the impetus supplied by such State "Enabling Acts", the City Council of Kenosha, Wis., appointed a City Planning Commission which,

"Immediately employed experienced and recognized consultants in city planning. Thorough and complete surveys were made. The character and extent of the city's past, present, and future growth, area, population, and topography were considered. Studies were made of new areas for the expansion of residence, business, and industrial districts. Thought was given to the effect the expansion of these areas would have on traffic, transit, transportation, schools, public recreation centers, housing, and grade-crossing hazards. A survey was made of the use of property, the location of public buildings, the means of transportation, and the new sewer and water systems. Definite conclusions based upon these surveys were formulated. Recommendations were made. Public hearings were had. The public was 'sold' City Planning by a campaign of education. The steps provided by Section 62.23 of the Wisconsin Statutes were followed and a comprehensive City Plan was adopted by the City Council. This plan created a City Plan Commission, established zoning, provided for a civic center, and determined the major streets."

Major Streets.—In regard to the planning of major streets, Mr. O'Brien emphasized the need of designing streets consistently so that thoroughfares intended for the same kind of traffic would have common characteristics, such as continuity, directness, and proper width. With this ideal in mind:

"The men in charge of the administration of the City Plan took action under four classifications which are as follows:

* Superv. Engr., Regional Planning Dept., Milwaukee, Wis.

"1.—Widening:
(*a*) Platting new subdivisions.
(*b*) Restricted building lines imposed either voluntarily or in deed of conveyance, or shown upon the recorded plat.
(*c*) Actual widening of present streets by condemnation proceedings under the power of eminent domain.
(*d*) The establishment of set-backs by legislation under the power of eminent domain.
(*e*) The establishment of set-backs or building lines by legislation under the exercise of police power.
"2.—Openings or connections.
"3.—Elimination of jogs and sharp angles.
"4.—Extensions in unplatted territory."

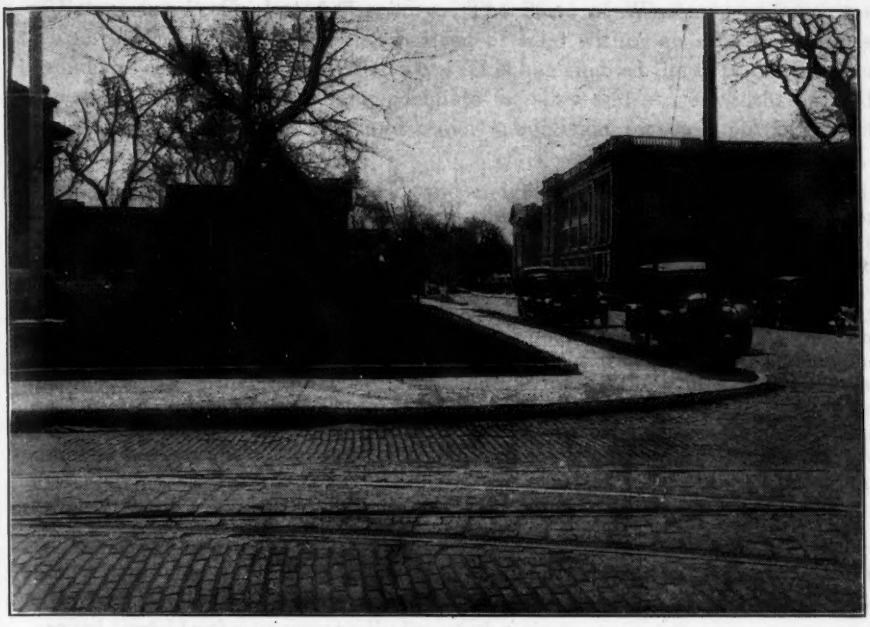
The City of Kenosha has made considerable progress in obtaining land for increased width of street by supervision of the subdivision of new developments. Even outside the city limits some control is enforced by requiring prospective builders to record building lines. In the present business districts, streets are being widened progressively by acquiring land through condemnation proceedings. When benefits and damages have been determined, the City pays a percentage of the cost which, in three instances, has been 48.5%, 20%, and 60%, respectively.

In establishing set-back lines, the practice was, not to move buildings back summarily, but to acquire land as needed, by right of eminent domain. The line was established with the understanding that new buildings should be set back to the new line. This feature was made part of the zone ordinance as follows (quoting Mr. O'Brien):

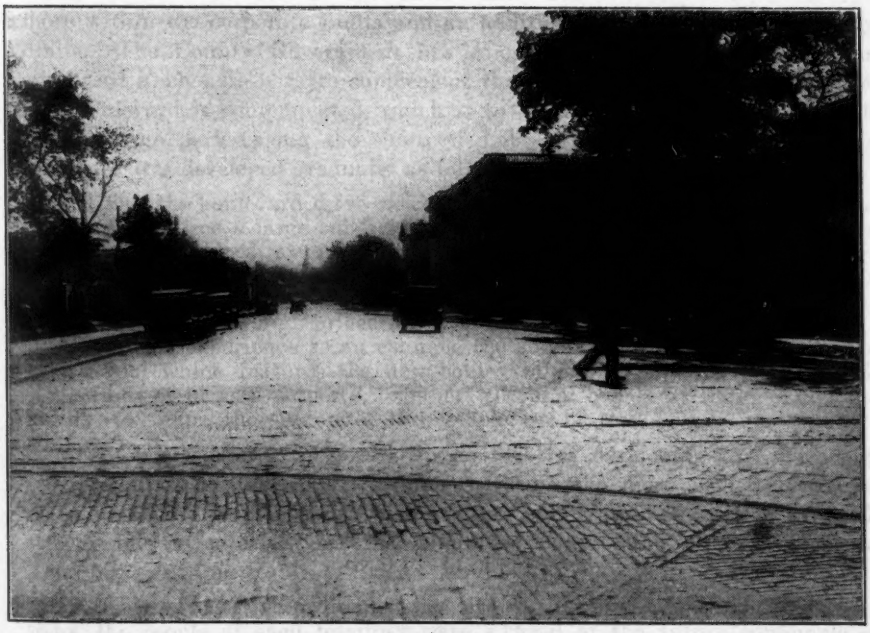
"A complete and thorough study of the needs and requirements of the major streets was made. Written into the ordinance are three major items; namely, a definition of a major street, the description of the proposed new center line of each major street, and the set-back from the center line required to obtain the proper width for each major street. This established a definite line of taking and measurements for each major street in the city. Being a part of the zone law the building inspector is held directly responsible for any infringements on the set-back line."

The City Plan Commission has given particular attention to the elimination of sharp angles, street offsets, and "dead end" thoroughfares. On this point, Mr. O'Brien states:

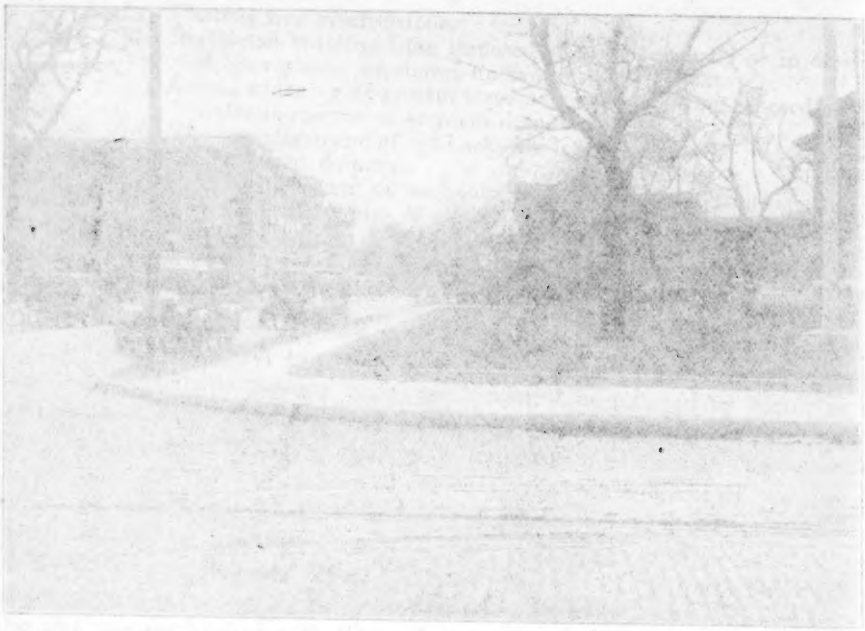
"A typical example of the procedure under this heading is the 7th Avenue extension through the property of the Union Tanning Company. This Company had a great deal of property, mostly built up. One of the buildings, a four-story structure, is directly in the line of the extension of 7th Avenue, a main street which will ultimately take a heavy traffic load from the central business section to the north portion of the City. The Union Tanning Company abandoned its plant and offered the property for sale. This afforded the city an opportunity to enter into competition with other bidders, and as a result a right of way 400 ft. long of the proper width for a major street was secured, cutting a four-story building in two, at a price of $35 000. Had this project been undertaken at the time when the building was being used as a going manufacturing unit the cost would have been so high as to have been almost prohibitive."



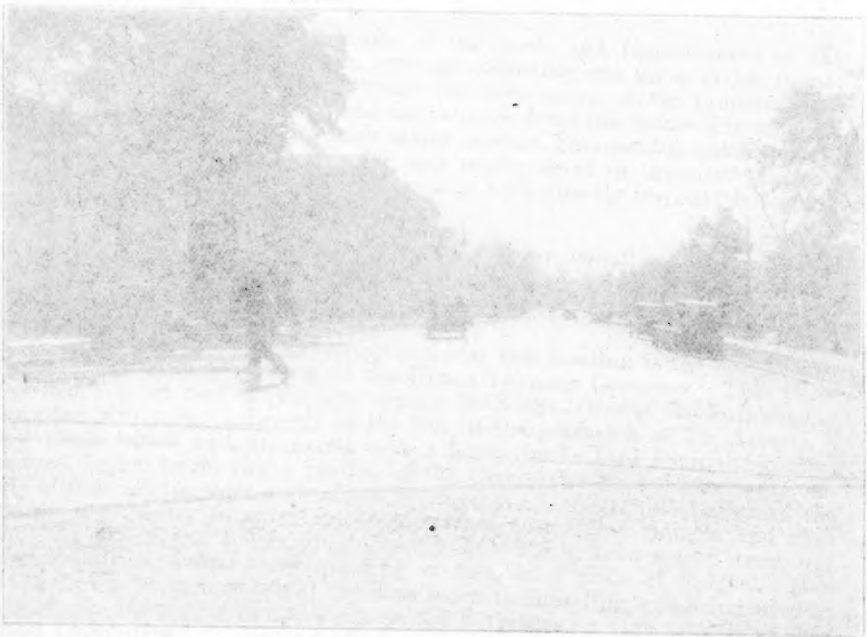
SHERIDAN ROAD LOOKING SOUTH FROM 56TH STREET, KENOSHA, WIS., BEFORE THE WIDENING.



SHERIDAN ROAD LOOKING SOUTH FROM 56TH STREET, KENOSHA, WIS., AFTER THE WIDENING.



Sheridan Road, Looking South from 20th Street, Kenosha, Wis.



Sheridan Road, Looking South from 20th Street, Kenosha, Wis.

Extensions in Unplatted Territory.—The State of Wisconsin gives power to a City Council to control the platting of land within an area three miles beyond the corporate limits of the city. This has enabled the City of Kenosha to secure provision for ensuring adequate lot sizes and street widths as well as a dedication of 5% of the land under subdivision for park purposes. In the words of Mr. O'Brien:

"With the future school, park, and neighborhood playground sites definitely located on the City Plan, when the subdivider presents his plat for approval by the City Plan Commission and the property includes one of the future sites above mentioned, the City will take its share of the 5% dedication and buy, at acreage price, the additional land necessary to complete the desired site within the subdivision. This work has been carried on very satisfactorily. The real estate men have co-operated with the City in this work and have used as a selling argument the fact that the park dedications or school sites which are within the boundaries of their new plats are an asset to the subdivision. Three future school sites have been secured at an acreage price far below what the same would cost if purchased at the time when needed. The other advantage of this system is that the sites are geographically located correctly to be of the greatest utility to the neighborhood which they serve."

Parks, Playgrounds, and Public Buildings.—The City Plan of Kenosha includes provision for neighborhood parks and playgrounds in connection with the sites for elementary schools. At present, four such sites have been secured, outside the corporate limits of the city.

The City Officials are taking aggressive steps to preserve the natural beauty of the creek ravines. The municipality has obtained 60% of the lake shore within the corporate limits and an additional 1½ miles outside the city limits. The County Government has co-operated with the City and has purchased a 400-acre park to supplement the remainder of the park plan. A long boulevard is contemplated, which is to be 120 ft. wide, passing through all the large parks along the shore of Lake Michigan. The idea of this boulevard was developed gradually as follows (quoting from the paper):

"At first the boulevard drive was accepted rather reluctantly. However, in the course of time a large subdivision was contemplated and platted, and the boulevard, as planned, extended through the center of this plat. The owners co-operated with the City, featured the boulevard, and placed the price of lots facing the wide street at about 20% higher than the lots on the adjacent narrow streets. The high-priced lots sold first at the advanced price.

"With this experience as an example the subdividers have been anxious to secure land which features the new boulevard and to date we have enough dedications of private property, together with that owned by the city and the county, to assure the success of the completion of this drive."

The Civic Center.—In line with the ideal of developing the city along practical lines, at the same time incorporating the more æsthetic features, there is to be a plaza, about which the future public buildings will be grouped.

Zoning.—A tentative "use" map simplified many of the zoning problems of Kenosha, according to Mr. O'Brien. To quote:

"After the tentative ordinance was drawn, the city was divided into sections, the people of each territory were advised of the future contemplated zoning of their property, and hearings were held for every section of the city.

This sectional map was so divided that the areas having a hearing on each successive day were comparatively small and, therefore, gave all the citizens equal chance to express their views as to what use was being demanded of their property. By using the present 'use' map as a base, there was very little objection to the zoning, and the same has held true since the adoption and the carrying out of the ordinance."

In zoning, "the density of population is regulated on the square-foot basis of lot area per family, and the maximum height limitation is placed at 100 ft. for commercial buildings." The Zone Ordinance has been quite successful. Of the 9 025 applicants for building permits during the period from January 7, 1924, to January 7, 1929, practically 96% conformed to all the provisions of the Zone Ordinance.

Sewer and Water Survey.—The water survey, made after the adoption of the city plan, was based on five major items: (1) Increase in population and relative growth of different parts of the city; (2) present and future water consumption and fire-protection requirements; (3) determinations of loss of head and coefficients of friction in trunk mains; (4) a general design in detail for reinforcing present mains and extending new ones; and (5) general plan for economical enlargement of present facilities.

The sewerage survey included a complete design of storm and sanitary sewers, based on expansion as contemplated by the city plan. A site was purchased for the proposed sewage reduction plant.

Financing the City Plan Development.—It was declared as a policy of the City Council that the improvements should be financed on a cash basis. In general, this ideal has been followed. As Mr. O'Brien states:

"Over a period of years an average of 9% of the entire general city budget has been appropriated to finance the city's portion of street widening, 6% of the general city budget for paving, and 5% for sewers.

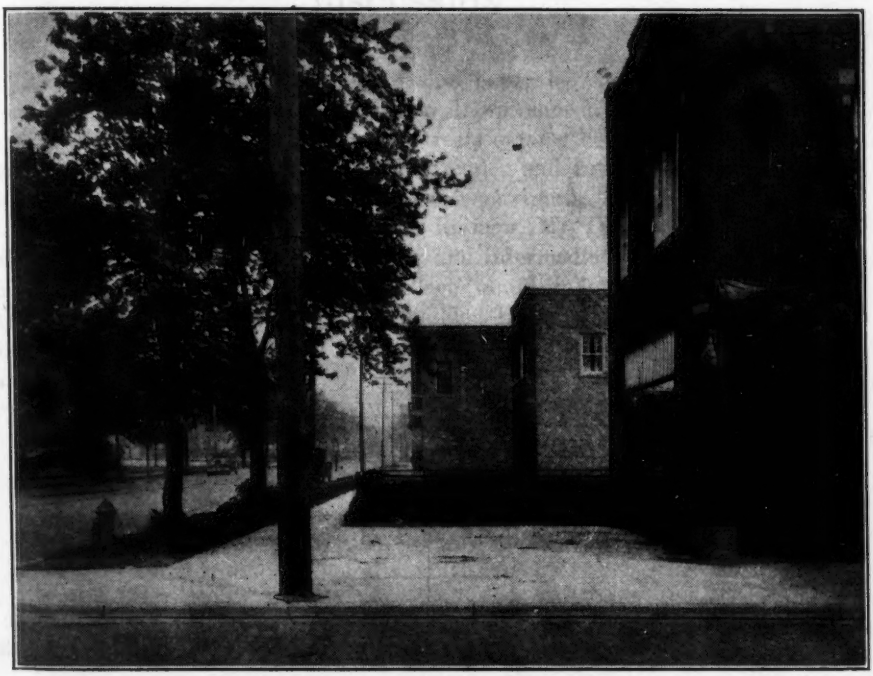
"The general plan for special assessments for sewers is the five-year spread method, and ten years for paving, the total improvement, uniform amount, and maturity serial bond being issued to cover the spread.

"Several years ago an amendment was added to the State Constitution, granting 'Home Rule' to cities. Taking advantage of this provision, the City of Kenosha adopted a charter ordinance allowing property owners to spread benefit assessments for street widening over a five-year period. At the time the Commissioners file their final report of the assessment of benefits and damages a period is set aside for the property owners to elect to pay cash or have bonds issued against their property to cover assessments of street widening. At the expiration of the set time the bonds are issued and placed on the tax roll to be collected in five equal installments. By this method the entire amount of assessments, not appealed, is available within ninety days after the date of filing of the final report by the Commissioners.

"A standing interim fund has been created from surplus and is known as the Revolving Fund. This fund is of sufficient size to provide payments to contractors pending assessment of benefits and the marketing of serial improvement bonds.

"The whole financial structure of the carrying out of the City Plan has been laid out with the idea of proceeding on the basis of carrying the city load without resorting to bond issues, and with the further idea that co-operation from the citizens can be better achieved by lightening their load and giving them the completed job before collecting the benefits.

NEW PLANT, KENOSHA, WIS., SHOWING SET-BACK.



SET-BACK, BEFORE AND AFTER WIDENING, KENOSHA, WIS.

"Kenosha's policy has proved successful. This statement is made from viewing the physical improvements completed and examining the tax value and rate. At the time of the adoption of the City Plan in 1922 the total assessment valuation was $54 938 400 and the tax rate per hundred dollars was $3.10, or a 31-mill rate. In 1928 the total valuation was $72 265 340, with a tax rate of $2.90 per hundred dollars, or a 29-mill rate. The valuation for assessing purposes in Kenosha is taken at about 57% of the true value. This percentage has not been raised and the increased valuation is due to the natural growth of the community. Considering the added service required by the taxpayers and the extra cost due to a larger city, we can truthfully say that by lowering the tax rate from $3.10 to $2.90 and still carrying on the public improvements and the work of City Planning that the financial structure or plan is sound.

"CONCLUSION

"The mere preparation of the plan does not secure its execution. A well-considered program spread over a considerable period of time and carefully adjusted to the financial means of the city is essential to a final carrying out of any City Plan. Many of the improvements recommended by a City Plan are regulatory in character and can be accomplished by passing comprehensive ordinances. A well-rounded plant that contemplates a systematic execution of all the major improvements required by a city during the next twenty or thirty years is a large program. To carry out and execute a city plan is at best an exceedingly difficult task. It requires ability and tact of the highest order, inexhaustible patience, courage, and determination on the part of the executive officials. It costs money, but with a systematic development, together with a sound financial policy, the desired results can be obtained."

DISCUSSION

Mr. O'Brien ended the reading of his paper by showing several slides illustrating the general points mentioned. It was shown, for example, that one feature of the plan is to have no cross streets enter a heavy duty street at an acute angle. All corners must be right angles and intersections are spaced as far apart as possible, 1 000 ft. being the maximum.

In reply to a question by Mr. M. I. Evinger, Mr. O'Brien explained that cross streets are numbered consecutively and intermediate streets are referred to as "places"; that is, Forty-third Place would follow Forty-third Street, etc. In answer to a question by T. Chalkley Hatton, M. Am. Soc. C. E., he stated that unsightly telegraph poles and wires are being removed as fast as possible.

CO-OPERATION IN THE CITY PLANNING OF MADISON, WISCONSIN

By E. E. Parker,* Esq.

Mr. Parker's discussion consisted of comments on the status of city planning in Madison, Wis. He stated that planning improvements in that city

* City Engr., Madison, Wis.

during the past thirty years have been largely due to the activities of the Madison Park and Pleasure Drive Association, with the assistance of voluntary subscriptions. In this way, from 50 to 60 miles of pleasure drives have been established throughout the region around Madison. The total expenditure of the Association has been about $3 000 000, largely for construction and improvements, planning, and maintenance.

The Association is now functioning primarily as a maintenance body. A new organization, the Madison Park Foundation, has become active in obtaining tracts of land for park purposes which are held until the City is in a position to take them over. Since 1924, according to Mr. Parker, the Foundation has acquired land valued at about $150 000, which the City has finally taken over. This money has been released for a new joint project with the University of Wisconsin, to be known as the Wisconsin Arboretum.

LEGAL PROBLEMS INVOLVED IN ESTABLISHING SET-BACK LINES

By Clifton Williams,* Esq.

In opening his subject, Mr. Williams made the distinction between set-back lines established for the purpose of future street widening and building lines established as a part of zoning ordinances. His greatest emphasis throughout was directed at the former.

Mr. Williams declared that, because of the tremendous toll of life and the acute problems of congestion caused by too narrow streets, to widen streets for the public good was fundamentally as much a sovereign right as the right of quarantine without compensation.

He stated his belief that:

"If the Courts would uniformly hold that the great American problem of widening streets so as to take care of present and future traffic needs is a problem of sovereignty * * * then * * * the streets and highways can be widened the same as buildings can be destroyed to prevent the spread of fire or the same as a high-salaried man can be quarantined to prevent the spread of disease."

As an example of a parallel case, Mr. Williams called attention to the fact that, when American engineers first made clear the potential congestion that might occur on Manhattan Island if every one should leave buildings and come out on the streets at once, the Courts were made to realize that the regulation of building heights was a function of sovereignty. Governmental authority had the right to restrict the number of people that might be concentrated in any one building by limiting the height to which buildings might be constructed. According to Mr. Williams, the engineering societies should assume the task of informing the Courts of the tremendous cost of converting the old "horse-and-buggy" streets into "automobile" streets. They should inform the Courts also of the tremendous loss of life and damage to property, caused by lack of adequate street widths. In other words:

* Special Asst. City Attorney, Milwaukee, Wis.

"The engineers of the land can do more than the lawyers at the present time in convincing the Courts that our present tremendous traffic problem, which is at the bottom of this requirement of set-back lines to street widening, is a phase of sovereignty."

While there is, in the Federal Constitution and the Constitutions of all the States, "a composite provision that private property shall not be taken for public use without just compensation", sovereign governments do destroy private buildings without compensation in order to stop the spread of fire. Mr. Williams declared that "when the Fifth Amendment to the Federal Constitution was written * * * no one had in mind preventing or stopping the further exercise of this recognized phase of sovereignty."

This point was amplified as follows:

"Now, if we can quarantine a person and cause his loss of salary without compensation, or if we can destroy his property to prevent the spread of fire, or if we can enter upon his land without compensation and build a levee to prevent the spread of a river—then if we can convince the Courts that the country is confronted with a very dangerous traffic problem, the solution of which is necessary to our existence as a people, then it is not a far step for the Courts to say that that traffic problem can be solved as a phase of sovereignty, and that the acquisition of the necessary property is not a prohibited taking within the constitutional provisions, any more than the other takings.

"At this time when the Courts have already held and are now uniformly holding that as a phase of so-called police power, or as an element of sovereignty, a State may say to a property owner that he cannot build above a certain line or that he cannot build within a certain distance from the street line in order to prevent more people from getting into a district than can be handled therein, or in order to make it easier to fight fires in the district, it is not asking the Courts to go very far when we ask them to recognize that the present traffic problems and the necessity for street widening, which includes the mild form of widening on notice, to-wit: the set-back line, is indeed a phase of sovereignty, and that the execution thereof can be carried out without compensation, the same as quarantine or the destruction of property for fire-fighting purposes and those other well-recognized phases of sovereignty."

Court Decision Concerning Set-Back Lines.—The validity of the set-back line in Wisconsin was established under a zoning ordinance that was tested in the Courts in 1927. Paraphrasing Mr. Williams, the decision may be expressed hypothetically as follows: A, who owned a corner lot, proposed to erect a house 15 ft. back from the property line along the main street, but ignoring the 15-ft. zoning ordinance as it applied to the side street. This brought Court action from B, whose view would be obstructed, to enjoin A from building within 15 ft. of both lines. The Court decided in favor of B.

In other words, A's property was, in effect taken for public use, without compensation. Declared Mr. Williams, A is,

"Merely in the same position that he would have been if buildings on these 15-ft. strips had been dynamited to prevent the spread of fire. He has no more claim against the public for compensation than if he had been quarantined away from a $25 000 job for two months to prevent the spread of smallpox."

A can cut the grass on these strips and plant flowers on them. He cannot build structures on them. On the other hand, if the City should attempt

to cut the grass or plant flowers, or if it should give sanction to traffic encroachments on these strips, A might justly claim compensation for damages.

Concerning this kind of police power, Mr. Williams stated that,

"Sovereignty recognizes no property rights. The self-preservation of a people is a law unto itself. A written Constitution is an agreement between the then existing units of people who make it a sovereignty concerning the exercise of the phase of government mentioned therein and there is not in existence a single Constitution which contains an abdication of all phases of sovereignty not mentioned therein.

"* * * a set-back line which notifies a property owner that within a reasonable time in the future it is apparent to the governmental authorities that the governmental sovereignty will be called upon to expand a street for the solution of this great threatening problem is much fairer to the property owner than the sudden destruction of his building to prevent the spread of fire or the peremptory and sudden quarantine of his body to prevent the spread of disease."

He predicted furthermore, that,

"For each case of apparent injustice and hardship where there may be a set-back line in a necessary widening of the street without compensation to the abutting owner, there will be dozens of cases where the widening of the street will create enormous additional property values. The advantage of the set-back line is that it can be so slowly and gradually worked out along the street as to remove most of the injustice. It might even be provided in such a law that if there must be a taking within five years of the establishment of the set-back line, that there will be compensation; but that there should be no compensation after a five-year notice of the establishment of the line. On some streets where we are looking far enough in the future we might even make the notice ten years."

In conclusion, Mr. Williams declared his belief that American Courts will some day declare that private rights must make way for the solution of the traffic problem as they now make way for the public control of fire, nuisances, crime, floods, and other forms of sovereignty.

DISCUSSION

THE USE OF SET-BACK LINES

By J. M. Albers,* Esq.

In opening the discussion on this subject, Mr. Albers declared that:

"Streets, adequate as to location, width, point of origin, and destination are of tremendous importance to proper civic development. Public safety and welfare are perhaps, to-day, more dependent upon the proper provision of streets than upon any other single function of government. The rapid growth of urban communities is continually demanding wider streets than were originally laid out. The larger the community the more difficult it is to secure the wider rights of way. The cost of condemnation is in many cases a greater burden than the community is able to bear and these highly necessary improvements are, therefore, delayed and sometimes abandoned to the detriment of the whole community."

* Sub-Division and Zoning Engr., Chicago Regional Planning Assoc., Chicago, Ill.

The establishment of set-back lines on the contrary is "painless" and economical. One of its decided advantages is that it requires the preparation of a comprehensive plan of future street improvements. According to Mr. Albers:

"The U. S. Supreme Court has said* that 'It is hard to see any controlling difference between regulations which require the lot owner to leave open spaces at the sides and rear of his house and a regulation which requires him to set his building back a reasonable distance from the street.'"

The Courts of Wisconsin, California, Ohio, and other States have sustained set-back regulations. In a case tried in Akron, Ohio, the Court decided that "the burden is upon the plaintiff to show that set-back lines bear no substantial relation to public health, convenience, and welfare before they can be declared invalid."

As regards present trends, Mr. Albers stated that:

"An examination of the authorities to date indicates that set-back laws are rapidly being sustained by the high Courts of the land as a proper exercise of the police power and that resort does not have to be made to the power of eminent domain with its attendant prohibitive expense. If such legislation is worked out by the governing body on the basis of a well-defined policy, after a careful study of the whole area affected and after due notice and hearing so as to avoid all charges of discrimination, arbitrariness, and unreasonableness, Courts will not interfere with such legislation. Such enactments will speedily justify their existence and there is a growing sentiment in favor of them in both the Courts and public opinion. When such legislation is predicated upon public health, safety, convenience, and welfare it is brought within the scope of a proper exercise of police power.

"In the Chicago Region many communities are now protecting future street widenings by the present establishment of set-back lines for this purpose. Some have passed ordinances creating such lines on specific streets, others are obtaining widening through agreement between the property owners and the city and village government. Still others have included the major street system with its required set-backs as a part of the zone ordinance. This latter, we believe to be the best method in that the city then has the opportunity to use the machinery set up in the Board of Zoning Appeals, and this body is in a position to adjust those difficulties which are bound to arise in so comprehensive a piece of legislation."

GENERAL DISCUSSION

In the case cited by Mr. Williams, the city apparently was given the right to establish set-back lines in the zoning ordinance. Could it extend the practice generally in the entire city for the purpose of future widening, but under the guise of zoning? This question was raised by F. W. Ullius, Assoc. M. Am. Soc. C. E. Mr. Williams implied that it could, since it was only a short step from zoning set-back to set-back for street-widening.

In discussing this paper, Mr. O'Brien stated that the buildings in Kenosha that must be cut off to supply added width in conformity with the plan, are valued at about $100 000 000. A close account of costs has been kept of the buildings constructed according to the new set-back laws.

* Case of Gorieb *vs.* Fox.

CONSTRUCTION DIVISION

JULY 11, 1929—9:40 A. M. TO 5:35 P. M.

This meeting of the Division was given over entirely to the reading and discussing of five Division Committee reports. It is hoped that, at some future date, the salient features of these progress reports will be incorporated in final reports to be published either in *Proceedings* or in separate manuals. After a few preliminary announcements, Chairman J. P. H. Perry introduced the subject of the first report on the program.

CONSTRUCTION PLANT AND METHODS FOR STEEL FRAME BUILDINGS

ABSTRACT OF COMMITTEE REPORT

By way of introduction, A. J. Hammond, Chairman of the Committee, called attention to the preliminary report submitted at the Annual Meeting of the Society on January 17, 1929.* This second report supplements the other, presenting data on pin-connected trusses, the erection of steel in sub-basements that are not excavated, and plant layouts for two large steel frame buildings which were built in record time.

Erection of Pin-Connected Trusses.—The Committee states that:

"Pin-connected trusses used for spanning large rooms of hotels and other public buildings must be figured for deflection and usually have considerable initial camber which must be considered when designing the falsework."

With proper care, timber bents built in advance can be handled with the regular steel-erecting derricks. Otherwise, special derricks may be necessary. In place, the falsework must be prepared to receive the total weight of the truss so that pins can be driven readily.

Erection of Steel Prior to Sub-Basement Excavation.—When this becomes necessary or advisable, "all columns and connections should be designed especially" with that in view, according to the Committee, and the designer and constructor can often work together to the advantage of both.

The process is to construct caissons and pour column footings, leaving the lagging in place to the surface of the ground. While the side and party walls are being built, the bed-plates and columns can be set. The steel beams and girders can also be set by digging the necessary trenches in advance of the general excavation work, but:

"This is a very slow and somewhat tedious process, particularly when deep girders are used. It will of necessity raise tremendously the pound price for erection of this part of the steelwork."

* *Proceedings*, Am. Soc. C. E., March, 1929, Papers and Discussions, p. 657.

The Committee gives the following as a typical equipment list electrically operated for a steel frame building with a 35-ft. tower:

"Two 100-h.p. derricks.
One 50-h.p. skip.
Three 100-h.p. cages.
One 125-h.p. concrete bucket.
Four 35-h.p. stone setting.
Six 2-h.p. winches.
Fifteen 2-h.p. caisson winches.
Three sets of rails with cages.
1 500 ft. of ¾-in. plow steel wire rope."

Plant Layouts and Hoisting Equipment.—The success of a contractor on steel building work will depend largely on the efficiency of his concrete and mortar plants. Removing rubbish and non-interference between various building operations are also important considerations. Building superintendents should make a thorough study of all possible stages of the work before any of it is actually begun.

A 38-Story Steel Frame Building.—The Committee submitted layout sketches of the construction plant for a 38-story office building in Chicago, Ill., which was completed about five weeks after the wrecking of the old building began. While the site was on a corner, with a 12-ft. alley along the third side, materials could be received only from one street. The layout of the concrete plant under these conditions is explained as follows:

"Three driveways, therefore, were built from this street into the building in order to provide ample receiving space for all materials. Truck loads of sand and stone for concrete were backed into the building on Drive No. 1 and dumped through a grating on the floor built of 3 by 12-in. planking set on edge at the rear of the drive. Below the grating in the basement a large hopper, divided into two compartments, one for sand and one for stone, was constructed. A 1-cu. yd. concrete mixer was placed on a firm foundation slightly lower than the bottom of the hopper while the concrete hoisting bucket rested in the shaft at a point lower than the discharge of the mixer. This arrangement proved ideal, for by means of drum batchers at the base of the sand and stone hopper and a system of chutes, the sand and stone could be quickly transmitted from the hopper to the mixer and then to the bucket. Cement in bags was dropped through a chute from the drive above and stored close to the mixer where one man could add the correct quantity to each batch. An average output of 40 cu. yd. per hour was made with this plant."

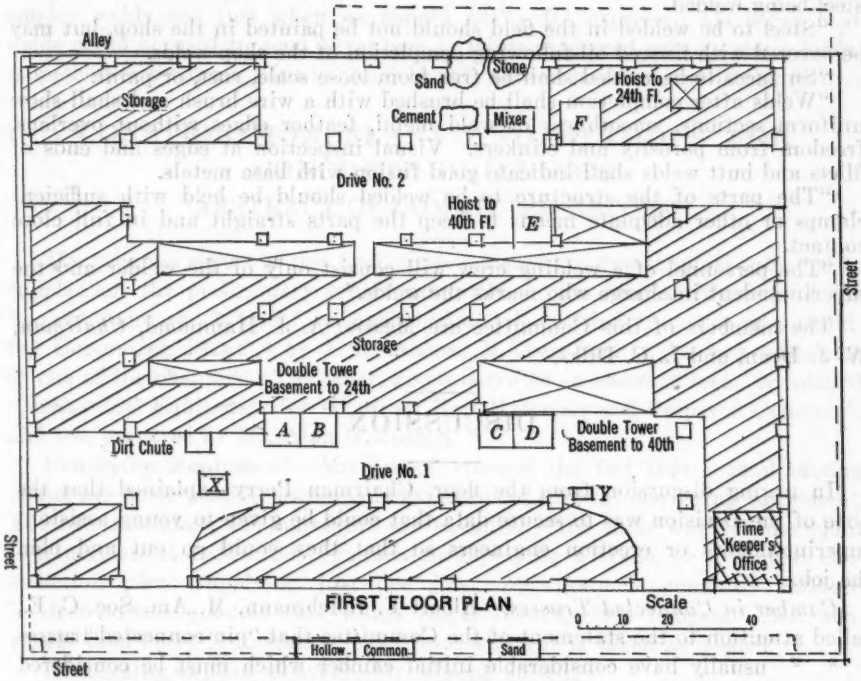
Common and hollow brick were hoisted at night and were stored on the floor where they would be needed. Face brick was hoisted from the curb at short intervals during the noon hour, thus making the greatest possible use of the hoisting equipment.

The Committee urges the need of keeping a construction job free from rubbish during the entire progress of construction, because it (1) reduces the fire hazard to a minimum; (2) eliminates obstructions to other operations; and (3) results in beneficial psychological effect on the workmen.

A 40-Story Steel Frame Building.—The other example of good plant layout cited by the Committee was in another Chicago building that had access to three streets and an alley. The general arrangement of drives, hoisting towers, mixing plants, etc., is shown in the accompanying diagram.

From the examples cited, the Committee lists four salient features conducive to efficiency in erecting steel frame buildings in congested areas:

(*a*) The plant layout on the ground;
(*b*) Materials storage facilities accessible to streets;
(*c*) Hoisting facilities intelligently located; and
(*d*) Refuse disposal facilities adequate.



PLANT LAYOUT, GENERAL ARRANGEMENT OF DRIVES, HOISTING TOWERS, MIXING PLANTS, ETC.

Erection of Welded Steel Frame Buildings.—The report included a short discussion of elementary principles of welding joints. The Committee recommended two papers for supplementary reference: "A Code for Fusion Welding and Gas Cutting in Building Construction",* and "Major Provisions of an Arc Welded Specification",† by Frank P. McKibben, M. Am. Soc. C. E. The report describes briefly the difference between electric arc welding and oxy-acetylene welding and concludes with the following list of requirements for welding in the field:

"One of the essential considerations is the preparation of the steel frame for welding by providing enough bolts to establish a rigid frame which after plumbing shall remain rigid under all erection and wind loads.

"Welding should follow erection as closely as possible.

* Code 1, Part A, Formulated by Committee on Building Codes, American Welding Society.

† *Engineering News-Record*, March 14, 1929, p. 425.

"Welders should have a service record of satisfactory welds which have been properly tested and of sufficient number to register competency of the man for either shop or field work.

"The superintendent of welders should indicate by chalk marks on steel the position and length of each individual weld.

"In electric welding the electrode should bisect the angle of a fillet weld when depositing weld metal.

"The welding electrode should have the same chemical composition as the steel being welded.

"Steel to be welded in the field should not be painted in the shop, but may be covered with linseed oil following completion of the shop welds.

"Surfaces to be welded shall be free from loose scale, rust, or paint.

"Welds after completion shall be brushed with a wire brush and shall show uniform sections, smoothness of weld metal, feather edges without overlaps, freedom from porosity and clinkers. Visual inspection at edges and ends of fillets and butt welds shall indicate good fusion with base metals.

"The parts of the structure to be welded should be held with sufficient clamps or other adequate means to keep the parts straight and in full close contact.

"The personnel of a welding crew will consist only of the welder and the superintendent in charge who marks the welds."

The members of this Committee are Messrs. A. J. Hammond, *Chairman*, W. J. Dean, and L. C. Dilks.

DISCUSSION

In urging discussion from the floor, Chairman Perry explained that the hope of the Division was to secure data that could be given to young assistant superintendents or erection engineers so that they could go out and plan the job.

Camber in Connected Trusses.—Albert F. Reichmann, M. Am. Soc. C. E., called attention to the statement of the Committee that "pin-connected trusses * * * usually have considerable initial camber which must be considered when designing falsework". This camber, said Mr. Reichmann, would be the same for pin connections as for other forms.

Welding Practice.—With respect to welding, Mr. Reichmann stated that he believed welding would be resorted to as a kind of reinforcement. To quote directly:

"I think it is going to be the practice that the carrying proportions of the structure will be riveted, in the hope that the welding will be primarily for taking care of wind stresses and things of that kind."

In defense of welding, he referred to the Chicago Great Western Railway Bridge at Fort Leavenworth, Kans. Some of the spans, 330 ft. long, were reinforced by welding about 1927 and the result has been perfectly satisfactory. The most necessary precaution in any case is for careful work in the field.

Field Tests.—In reply to a question by J. L. Fyfe, M. Am. Soc. C. E., Mr. Hammond stated that shop tests of welded joints had been developed, but that in the field it was largely a matter of visual examination.

This explanation was further amplified by Clyde T. Morris, M. Am. Soc. C. E., who explained that it is difficult to judge the strength of a weld by a

surface examination. The responsibility for the weld rests in the reputation of the welder. Therefore, welders themselves have been tested to determine their reliability. In other words, the welder submits samples of his work which are tested in the shop. The purpose of the test is to "qualify the welder and not to test the value of the weld".

According to Edward Haupt, M. Am. Soc. C. E., the art of welding has not progressed far enough to permit final judgment as to "just when we should employ welds and just when we should not". He expressed his belief that welds could be used to good advantage at joints subjected only to static loads. A method of testing a joint in the field will have to be developed in the future.

CONSTRUCTION PLANT AND METHODS FOR CONCRETE BUILDINGS

ABSTRACT OF COMMITTEE REPORT

The progress report of this Committee consisted of two chapters intended to supplement the preliminary report submitted at the Annual Meeting of the Society, January 17, 1929.* A published article entitled "Analysis of a Building Concreting Plant",† by J. G. Ahlers, M. Am. Soc. C. E., was submitted as one of the chapters. The other, given herewith in abstract form, is entitled "Mechanical Equipment for Handling Raw Materials and Prepared Concrete", and was prepared by Mr. Alan H. Joseph.

Conveying Equipment.—Mr. Joseph stressed the fact that central mixing plants are made possible principally by means of efficient conveying equipment. For raw materials, the conveyors are essentially the same whether the plant is a permanent industrial organization supplying a trade, or a central construction plant supplying just one job. Aggregate is generally received in drop-bottom gondola cars which empty directly into hoppers. Belt conveyors then carry it to storage piles from which it is taken as needed.

Concerning cement delivery, Mr. Joseph stated:

"Bulk cement received in box cars is unloaded by a scraper device usually operated by one man. The cement, as it is discharged from the car, enters an enclosed elevator which raises it to an enclosed storage bin over the plant."

Mr. Joseph recommends the installation of dry pre-mixers to secure better concrete. He also commends the use of belt conveyors for transporting mixed concrete from the plant to the forms, because they consume less power than a skip hoist; they have a high continuous capacity; they are easily portable; and the cost of maintaining them is low.

In conclusion, Mr. Joseph stated: "Belt conveyors are justified only when they are compared with other forms of conveying equipment on the basis both of first cost and cost per cubic yard handled".

This Committee is made up of the following: Messrs. A. P. Greensfelder, *Chairman;* J. G. Ahlers, L. N. Beals, W. C. E. Becker, G. G. Black, H. M. Cryder, M. C. Emanuel, H. E. Frech, A. H. Joseph, R. L. Rinehart, E. O. Sweetser, Harry F. Thomson, L. R. Viterbo, and F. C. Woermann.

* *Proceedings*, Am. Soc. C. E., March, 1929, Papers and Discussions, p. 649.
† *Engineering News-Record*, May 23, 1929, p. 837.

DISCUSSION

Mr. Joseph amplified the report orally in discussion. In particular, he declared that,

"The use of belt conveyors for distributing prepared concrete is a new idea in the contracting business. * * * Of course, belt conveyors cannot be applied everywhere. * * * The job must be analyzed to see what type of installation is best and various types of belt conveyors are found adaptable to various installations."

Chairman Perry quoted some data relating to the company with which he is connected. Labor on concrete work for that company produced 149 units of construction (say, cubic feet) in 1921 and 179 units in 1928, on the basis of 100 units in 1913. Continuing:

"Another way of emphasizing the importance of considering plant and methods in construction is the fact that in 1913 on our company's work, labor was 38% of the cost of the job. Last year (1928) it was 51% * * *."

The increase in output per man-hour of carpenter work, he stated, had been only 10%, whereas concrete labor showed the greatest unit improvement.

Efficiency of Dry Pre-Mixers.—"How much increase can you gain by dry pre-mixing and what is the cost of installing a dry pre-mixer as compared with installing an increased capacity of wet mixer?" This question was asked by R. C. Johnson, Assoc. M. Am. Soc. C. E., and, in reply, it was explained that the relative economies in any case depend on the requirements of the job itself.

Mr. Joseph declared that the dry pre-mixer is simply an auxiliary machine placed ahead of the wet mixer to take some of the work. The result should be much better concrete and, for high-grade concrete, should be more economical. No specific data were available at the meeting.

CONSTRUCTION PLANT AND METHODS FOR CONCRETE ROADS

ABSTRACT OF COMMITTEE REPORT

This report was read by E. K. Abberley, M. Am. Soc. C. E. As in the case of other reports read at this meeting, it was supplementary to the corresponding paper presented at the Annual Meeting on January 17, 1929.*

Number of "Set-Ups".—The relation between the location of the job and the nearest railroad will do much to determine the location of the contractor's plant. According to the Committee:

"Most contractors do not care to figure over a three mile maximum haul either direction from their plant site, and where another set-up at reasonable cost can be obtained, two set-ups are generally cheaper than one when there is a longer haul. Under such conditions the economic number of set-ups depends entirely on the length of the contract."

* *Proceedings*, Am. Soc. C. E., March, 1929, Papers and Discussions, p. 639.

Railroad Facilities.—The possible choice of railroads for yard facilities was next considered, as follows:

"The contractor is usually limited to not more than two railroads; generally there is only one choice, but where there are two or more, care should be taken in considering all the governing points and advantages each line may offer. Competition in railroads is good."

A number of considerations that would influence a choice of railroads were given. Among them were: The source of materials; their cost, f. o. b., at the plant site; reliability of service; relative location of railroad and plant; construction track crossing railroad track at grade; length and cost of track installation; interference with industrial tracks; interference with other contractors' track; etc.

General Considerations.—For simplicity it was assumed that the job could be served by a simple "set-up". In more than half the cases a contractor will have no choice. When he can choose between available sites, some of the factors to consider are: Topography, excessive rental charges, nature and quantity of contractors' hauling outfit, space available for track layout and switching operations, water supply, proximity to camp site or to town, electric power supply, etc.

Plant Layout.—According to the Committee, the space available will often limit the plant layout, but:

"In all events the plant site must be so arranged that there will be no difficulty in keeping the paving outfit running. Experience has proved that the average mixer can lay a capacity yardage of pavement daily if means are provided to get the materials to it; therefore, it all hinges around the ability of the contractor to unload, store, and haul his aggregates, and the plant must be designed with this in consideration."

Switch Tracks and Switching.—On this subject, the Committee states:

"The railroad switch tracks must be long enough to handle at least a full day's supply of coarse and fine aggregates with room for the empties, and preferably, the siding should be cut into the main line at both ends (this is often difficult on account of grade). The matter of switching facilities will influence the length of track. Ordinarily, it is poor practice to do any switching during the day if it can be avoided, because at such times the operations of the unloading crane are at a standstill. The average job can get one, possibly two switches a day; therefore, it seems hardly practical to specify a storage track greater than the capacity for a single day's run plus a normal increased length for emergencies.

"If possible, there should be such a grade that the loaded cars can be moved to the crane or past the storage bins by gravity. If a locomotive crane is used, it will of course be necessary to have a second track for it, and this track should be long enough to handle the storage piles and the unloading bins. If the space is available, it is best to have a separate track leading to the cement house. This will overcome the danger and necessity of continual moving of the cement cars due to other switching operations. If there is not a separate track to the cement shed, the latter should be located at such a distance from the loaded aggregate cars that there is room enough between them for a day's run of empties. Probably the most logical method of handling cement from the main switch is to put the cement house on the far end of the track, then the switching of aggregate cars will not disturb the cement cars. Of course, if the track is cut in at both ends, this difficulty is avoided.

"There are several ways of moving loaded cars in the yard when switching facilities are not available. The locomotive crane is, of course, the most advantageous switch engine that one can secure. The caterpillar crane or tractor with cable will also serve.

"In placing material cars on the siding one of the most important points is to see that they are spotted in proper order with relation to cement, stone, and sand. That is, in a day's run the proper number of cars of each commodity should be placed in line to avoid cutting out empties."

Storage Piles and Bins.—Steel bins are now commonly used for storage purposes. The minimum capacity of the bins should be such as to keep the plant running for one hour, according to the estimate of one contractor. They must be located so that the unloading crane can work direct from car to bin.

Cranes and Unloading Practice.—For the average country road job, the crawler type of crane is recommended instead of the heavier locomotive type. One suggested arrangement for unloading purposes is described as follows:

"A crane will swing 180° in about the same time as it will hoist a bucket to the height of the bins. The crane moves parallel to the track and a stock-pile in the form of windrows can be made on one side of the bins for the coarse aggregate and on the other side for the sand. The height of the stock-piles will be only about the height of the bins, and, of course, the capacity can be gained by elongating the pile. The crane should be placed so that it swings to about a 2-ft. clearance of the cars.

"A stiff-leg derrick hoists faster than it swings, so it is desirable to place the bins adjacent to the track. As a general rule they should be placed adjacent to the track in the same segment of the swing as the sand stock-piles and the coarse aggregate piled in the other segment. Such an arrangement allows a large stock-pile of coarse aggregate which is, of course, desirable since only half as much sand is used as coarse aggregate. Filling the bins with any method, the bucket should be dumped in one corner for the coarse aggregate and the diagonal corner for the sand. This will allow the boom to be raised or lowered enough to clear the cars and still drop the material into the bins."

The report also describes present best practice in regard to location and equipment of cement houses, shops, offices, commissaries, camps and central mixing plants. It also discusses hauling equipment, industrial haul, truck hauling, and the transportation of cement.

In line with the avowed purpose of these reports, it is expected that most of this material will appear as a final report at some future time.

This Committee is as follows: Messrs. Ralph R. Benedict, *Chairman*, L. R. Ames, C. W. Brown, H. B. Bushnell, H. A. Camlin, G. E. Hamlin, C. M. Hathaway, A. H. Hunter, A. A. McCree, F. H. Mann, F. B. Oren, P. M. Tebbs, B. C. Tiney, and C. R. Weymouth.

DISCUSSION

How far is it safe to haul concrete from a commercial mixing plant for concrete pavement? This question by N. T. Veatch, Jr., M. Am. Soc. C. E., was discussed at some length by W. C. Hammatt, M. Am. Soc. C. E., who called attention especially to observations on a central mixing plant at Austin, Tex. One contract that it supplies entails a haul of four or five miles, so it was important to know the extent of segregation.

After carrying it for about 45 min., one batch was returned to the plant and examined. There was very little segregation in dry batches, according to Mr. Hammatt. He felt that the segregation of aggregate that he had observed, was probably due to excess water.

Cement Added at the Batching Plant.—George L. Wilson, M. Am. Soc. C. E., questioned the superiority of the practice of adding cement at the job instead of at the batching plant. The latter method is gaining favor, he stated, because it can be done more properly. Furthermore,

"Sacks, when they are dumped by hand, are never completely dumped, and the amount remaining will vary considerably. In fact, I have recently seen a cement cleaning machine used, in which the contractor salvaging the material remaining in sacks, saved very materially on the cost of his cement. It seems to me, if the wet aggregate is not so wet as to make the addition of the cement at the batching plant subject to a preliminary set on the way out, that the addition of the cement at the batching plant will be much preferable."

CONSTRUCTION PLANT AND METHODS FOR HYDRO-ELECTRIC INSTALLATIONS

ABSTRACT OF COMMITTEE REPORT

This report was read by A. J. Hammond, M. Am. Soc. C. E. It constituted an elaboration of the last paragraph of the report read at the Annual Meeting, January 17, 1929,* dealing with machinery installation.

The Committee calls attention to the importance of a carefully prepared shipping schedule to control the arrival of different parts of the machinery as needed. Temporary storage space will have to be provided for some of the smaller pieces until they are needed, but often the larger pieces may be unloaded directly and placed in their permanent position. For this reason, cranes should be supplied that will handle such machines.

The report contains detailed erection schedules for water-wheels, generator and electrical installations, so arranged as to follow in logical sequence.

The members of this Committee are: Messrs. W. L. Locke, *Chairman*, L. V. Branch, and E. C. Macy.

CONSTRUCTION PLANT AND METHODS FOR CONCRETE BRIDGES

ABSTRACT OF COMMITTEE REPORT

This report was in two distinct parts: The first a discussion of the factors that affect a bridge contractor's bid; and the second, a discussion of pumping equipment.

In a large percentage of cases, construction work is awarded to the "low bidder" without questioning his ability to insure satisfactory performance. In

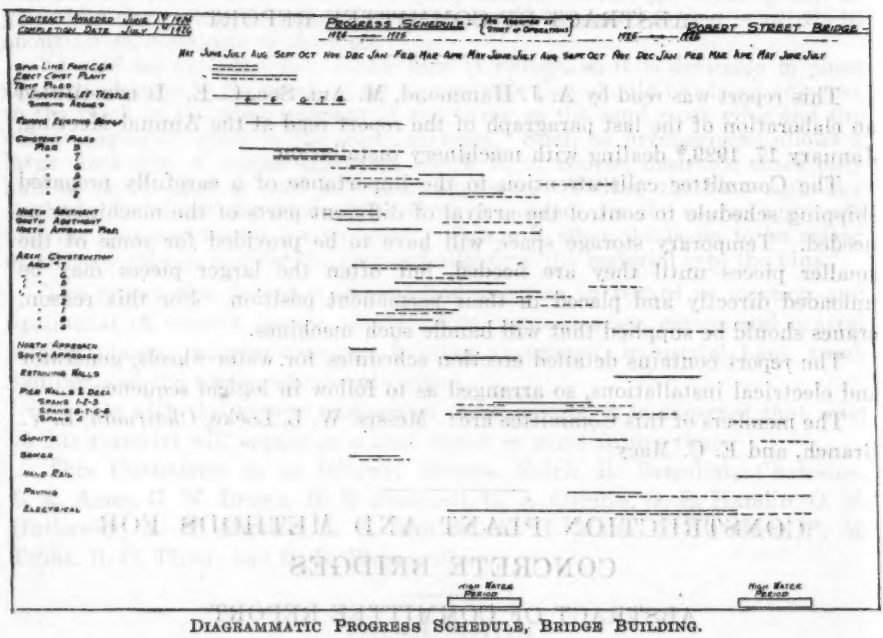
* *Proceedings*, Am. Soc. C. E., March, 1929, Papers and Discussions, p. 640.

the opinion of the Committee, no contractor is justified in submitting a bid unless he has visualized the work in terms of at least one method of attack. In other words, "method of procedure influences the cost of the completed structure far more in bridge building than in many other classes of work."

Stream Studies.—If a bridge is to cross a stream that is subject to flood flows, this fact will be one of the first considerations. Information concerning past performance will be furnished by the U. S. Geological Survey, by near-by power companies, or by old settlers in the vicinity.

The bridge builder will have to estimate the length of time available for constructing coffer-dams, falsework, etc., in low water, and his estimate should be conservative, according to the Committee, so as to allow a margin of safety under average conditions.

Progress Schedule.—Examples of diagrammatic progress schedules were submitted, one of which is included herewith. The order of the work as planned is shown by the dotted lines and the order as actually carried out is drawn later by solid lines. Such a graph makes it possible to arrange work tentatively so as to make the best possible use of the equipment and construction staff.



DIAGRAMMATIC PROGRESS SCHEDULE, BRIDGE BUILDING.

After the general requirements for the entire job are thus developed, the Committee recommends planning work in greater detail in advance for three-month periods.

Staff.—The selection of men for the Construction Staff receives emphasis in this report. Specifically, the Committee states:

"Not many contractors' organizations are perfectly constituted to handle bridge building. No qualifications are too high for the ideal personnel. Cour-

age, judgment, managerial ability, building sense, and resourcefulness of high order are necessary to carry out successfully a large bridge project. Undertaking such project, without having men available for direct supervision, who have had previous experience with such work and with the Company organization, would certainly jeopardize the progress and profit of the job."

* * * * *

"Bridge building, after all, is a business, and without knowledge of the fundamentals of good business, performance and cost will soon remove the bridge builder from that field of endeavor."

Importance of Safety.—Care in avoiding accidents was stressed as follows:

"It is the duty of any employer to provide a safe place to work. It is, furthermore, decidedly profitable to see that such condition exists. A job should be laid out having in mind that during the life of the work, men will travel hundreds of man-miles in the prosecution of their duties, and carry many tons of materials from place to place. Well-established routes, safely constructed and well maintained, will pay good dividends. No man will deliver maximum output if part of his attention and energy is needed for self-preservation—make his scaffold safe, discard a much used ladder for a stair, see that guards protect a man during a careless moment. Clean up the trash that causes many circuitous routes, and menace thin-soled shoes with rusty nails. Accidents affect not only the unfortunate individual, but demoralize their fellow workmen."

Pumping Equipment.—In bridge foundation work, a thorough knowledge of pumps is essential. The opinion of the Committee is summed up in the statement that:

"The construction engineer in purchasing pumping equipment should bear in mind that continuous, uninterrupted service is far more important than any other item. Time is the essence of a contractor's life."

For heads of 150 ft., a centrifugal pump is recommended; and especially if the water is somewhat "gritty", it was said to outlast the power pump. In coffer-dams under heads from 5 to 50 ft., centrifugal pumps were given preference over power pumps or gasoline-driven diaphragm pumps because "the first cost is comparatively low, they are easily operated, economical, and have a low maintenance cost."

The performance of the ideal centrifugal pump for coffer-dam work, according to the Committee, will be such that its head-capacity curve is steep and the horse-power and efficiency curves are flat.

The remainder of the report was a discussion of the size of units required and descriptions, with illustrations, of various types of pumps. The relative advantage of open and enclosed impellers was treated as well as the advantages of steam as compared to gasoline. It was stated that steam power "has practically been eliminated from construction work, due to the necessity of handling coal for boilers. * * * Electric motors have been used very extensively, but they present some disadvantages in comparatively remote places."

The Committee also described the advantages and disadvantages of Diesel engines and of belted *vs.* chain drives. A description of the uses and the accessories of the jetting pump closed the report. This Committee is composed of two members: Messrs. D. B. Fegles, *Chairman,* and E. H. Connor.

DISCUSSION

Mr. A. J. Hammond related incidents that illustrated the importance of investigating the question of borings before beginning to lay out the construction plant. These were reinforced by incidents in the experience of Mr. Edward Haupt. Difficulties are most often caused by misleading information given in plans and specifications. Mr. Haupt's opinion was that "information should be given to the contractors that is the best obtainable. Then, if it is found that conditions are not as shown or indicated by the plans and specifications, the owner should bear the brunt".

HIGHWAY DIVISION

JULY 11, 1929—2:45 P. M. TO 4:50 P. M.

One subject opened for discussion at this meeting was the equitable distribution of license fees and gasoline taxes. This subject is being discussed objectively at four meetings during the current year; namely, Dallas, Tex., in April; Milwaukee, Wis., in July; Boston, Mass., in October; and New York, N. Y., at the next Annual Meeting in January, 1930. The purpose in continuing this discussion, as explained by Chairman J. H. Ames, is to obtain an expression of opinion on this subject from widely separated parts of the country.

EQUITABLE DISTRIBUTION FOR HIGHWAY PURPOSES OF MOTOR VEHICLE LICENSE FEES AND GASOLINE TAXES

By George B. Sowers,* M. Am. Soc. C. E.

In addition to preparing and reading this paper at the meeting, Mr. Sowers very kindly submitted his own abstract, which is presented herewith:

"A Scientific Study Needed.—In the upward swing of the pendulum of gasoline taxation, several problems are being accentuated that are of direct interest to engineers and city officials in charge of construction and maintenance of roads, to every voter in the cities, and in another way to every motorist on the highways. It is not so much that there is a protest against the frequent increases in the gasoline tax, as a dissatisfaction with the distribution of the tax money. Many of us feel that those who pay the tax are not deriving benefits in proportion to the advancing payments. The time has come to make a scientific study of the factors involved and to devise a new basis of distribution that will be both equitable and practicable in the service of all groups of people.

"Recent Development.—Seven States have increased their tax on gasoline during the past year and one-half. Three States have adopted their first gasoline tax. In Louisiana, the tax was increased from 2 cents per gal. to 4 cents per gal. In Virginia, the tax is now 5 cents per gal. South Carolina has the maximum tax of 6 cents per gal.

"History of the Gasoline Tax.—The tax on gasoline for pavement construction and maintenance purposes first made its appearance in 1919. This year marks the collection of a gasoline tax in every State of the Union and the District of Columbia. No State will collect less than 2 cents per gal.; one State is collecting 6 cents; nine are collecting 5 cents; nineteen States are collecting 4 cents. The average rate has increased to 3⅞ cents per gal.

"The demand for more and better pavements continues. The motorists are willing to pay for their roads in proportion to the use which they make of them. The chief reaction is against the inequitable distribution of the proceeds of the tax. The urban motorists are protesting against the unfairness of using substantially all the money on State roads outside of municipalities and not providing funds for the construction and maintenance of the pavements which they use each day in their municipalities.

* Deputy Commr., Div. of Eng. and Constr., City of Cleveland, Cleveland, Ohio.

"The Present Status of Pavement Financing.—Three general methods for providing the funds required to pay the cost of building pavements in municipalities are now in effect:

"1.—The real property especially benefited may be assessed for some part or all of the cost.

"2.—A general tax may be levied on all the property in the municipalities to pay for pavements.

"3.—A gasoline or wheel tax may be collected. Very few cities have resorted to a local gasoline tax. It has been found that such a local tax forces the motorist to purchase his gasoline at the city limits.

"Division of Pavement Cost.—The strength and width of the pavement required in any thoroughfare depend fundamentally upon the number of gallons of gasoline consumed, in a unit of time over a unit length of the pavement.

"The property owners along a highway or a city street should only be asked to pay for the cost of a pavement which is of sufficient width and strength to provide for the local uses of the property owners. The public must assume a larger part of the cost of building the pavements in the municipalities.

"Gasoline Tax.—The gasoline or fuel consumed per mile of roadway probably is the most exact measure which we have of the service which a pavement renders to a motor vehicle owner, whether he is operating a passenger car, a bus, or a motor freight train.

"A tax of a few cents on each gallon of gasoline consumed on the roads and city streets of any State is unquestionably the most equitable and just form of assessment or tax for the construction and maintenance of pavements other than required for purely local use.

"The amount of any gasoline tax is probably governed by what the traffic will bear. If the proceeds of such a gasoline tax were scientifically and equitably apportioned to the building and maintaining of pavements the motorist should justly consider it a part of the cost of using the motor vehicle and as such he should be willing to pay whatever fee is needed to provide and maintain pavements for his use.

"Distribution of Gasoline Tax Money.—The distribution of money for pavement construction and maintenance derived from a tax on gasoline on the basis of the number of gallons of gasoline consumed on the pavement is the ideal method of distributing such a fund.

"Either a portion of the gasoline tax fund should be turned over to the municipalities for the maintenance of the pavements within the municipality or the State Highway Department should include a large part of the municipalities' pavements in the State system of highways for the purpose of reconstruction and maintenance.

"The highway engineers in the country should work together in the development of an equitable and scientific method for the distribution of the funds derived from the tax on gasoline."

DISCUSSION

EQUITABLE DISTRIBUTION FROM AN ECONOMICAL POINT OF VIEW

By Henry R. Trumbower,* Esq.

Development of License Fees and Gasoline Tax.—Quoting data from the files and publications of the U. S. Bureau of Public Roads, Professor Trumbower analyzed the method in which funds are at present distributed. In 1901,

* Prof. of Economics, Univ. of Wisconsin, Madison, Wis.

New York State collected $954 by licensing automobiles. In 1928, the total collected from this source in the United States was $322 630 000. On the other hand, the first gasoline tax law was passed by the State of Oregon in 1919. In 1928, the total revenue from this source among all States was $304 872 000. The general theory that underlies the gasoline tax principle, according to Professor Trumbower, is "that the people who use the roads should pay for them and that a tax on gasoline measures, to a certain extent, the wear and tear on a highway from an automobile passing over it."

Expenditures for Highway Purposes and Motor Vehicle Revenues.—What happened to the $627 500 000 collected from license fees and gasoline taxes in the United States during 1928? This was a question of especial interest to Professor Trumbower. To dispel the idea, held by many people, that income from license fees and gasoline taxes pays for all highway improvements, the following tabulation was submitted, which shows that less than one-half the money spent, is collected from these sources.

RELATION OF LICENSE FEES AND GAS TAXES TO TOTAL INCOME FOR HIGHWAY PURPOSES.

Year.	Total expenditures for highway purposes.	Total Revenues from License Fees and Gasoline Taxes.	
		Amount.	Ratio to total highway expenditures.
1921	$1 036 387 722	$127 780 913	0.123%
1922	*	163 971 265	.....
1923	996 781 038	225 784 931	0.226
1924	1 181 521 115	305 226 742	0.258
1925	1 288 939 707	406 648 561	0.316
1926	1 300 545 632	475 905 383	0.368
1927	1 350 000 000†	559 899 945	0.414
1928	1 400 000 000†	627 501 791	0.446

* Data lacking.
† Estimates.

The total expenditures do not include money spent for construction, maintenance, and repair of city streets.

Gasoline Tax Revenues.—In 1921 the average cost for license fees and gasoline taxes was $12.20 per vehicle. Only thirteen States imposed gasoline taxes and the average rate was 1 cent per gal. In 1928, all but two States imposed such a tax, and the average, as compared with $12.20, was $25.60 per vehicle.

Distribution of Motor Vehicle Revenues.—The actual distribution of revenues received in 1928 is listed in the tabulation included herewith. The remainder of the discussion was reserved for detailed comment on the data in this tabulation. Professor Trumbower called especial attention to the fact that 85.5% of the motor vehicle revenues were used for the maintenance and construction of rural highways. He declared, furthermore, that:

"In recent years there is noted this tendency for certain of the States to issue bonds for highway construction purposes and provide at the same time that motor vehicle revenues be used to meet the annual interest payments and retirement payments. * * * This policy has been, to a certain extent, responsible for increases in gasoline tax rates."

DISTRIBUTION OF 1928 MOTOR VEHICLE REVENUES.

Item.	LICENSE FEES.		GASOLINE TAX.		TOTAL.	
	Amount.	Percentage.	Amount.	Percentage.	Amount.	Percentage.
Collection and administration..	$ 15 133 999	4.7	$ 694 601	0.2	$ 15 828 600	2.5
State highways.....	208 880 272	64.7	211 046 591	69.3	419 926 863	66.7
Local roads.....	60 399 109	18.7	57 380 901	18.7	117 780 010	18.8
State bonds.....	29 857 189	9.3	14 269 124	4.7	44 126 313	7.1
County or local bonds.....	1 968 722	0.6	3 350 871	1.1	5 319 593	0.9
City streets and city use.....	3 931 412	1.2	7 830 719	2.6	11 762 131	1.9
Highway traffic control.....	1 932 845	0.6	.....	.....	1 932 845	0.3
Miscellaneous purposes.....	526 477	0.2	10 298 959	3.4	10 825 436	1.8
Total.....	$322 630 025	100	$304 871 766	100	$627 501 791	100

Referring to funds for city street and city uses, Professor Trumbower stated that:

"There seems to be a growing feeling on the part of cities and municipalities that they should share in the annual motor vehicle revenues, especially the gasoline taxes. The argument usually advanced in favor of such a policy by city representatives is based on the fact that municipal expenses have been greatly increased on account of the motor vehicle; that the maintenance of city streets has greatly increased; and that the costs of traffic control by the police department have advanced very much because of the increasing amount of motor vehicle traffic. There is no doubt that every city could render a very substantial bill involving city expenditures caused directly or indirectly by the use of the motor vehicle. Another argument is to the effect that many motor vehicles are burdened with the gasoline tax which hardly ever are operated over rural highways, and that revenues derived from them should in large part be credited to city governments. And there is a good deal of merit to their argument. On the other hand, traffic counts and surveys have shown* that the State highway systems are used to a much greater extent by motor vehicles owned in cities than by motor cars and trucks owned and operated by rural dwellers."

* * * * * * *

"It is, therefore, obvious that to the extent that cities are successful in taking away funds which would ordinarily be spent on rural highways, the rural highway program is either retarded proportionately or other sources of revenue will have to be found. It is generally agreed by those who have studied the problem that rural property, real and personal, is taxed about as much in that case as that kind of property can reasonably bear. In certain States cities attempt to get additional revenues from motor vehicles by charging an annual wheelage tax or a license fee in addition to the State license fee."

Items which, it was pointed out, should logically be paid for by the operators of motor vehicles are: Supervision, control, and regulation of traffic as well as cost of snow removal, etc.

Practice varies in certain States as to the disposition of funds outside the pure dominion of highway construction and maintenance. Some States have used part of motor vehicle taxes for school purposes; one State built a sea wall

* Report of a Survey of Transportation on the State Highways of New Hampshire by U. S. Bureau of Public Roads and New Hampshire State Highway Department, 1927, p. 7, and *Public Roads*, June, 1927, p. 62.

for highway protection; another paid for flood damages; and still another built an office building for its State Highway Commission.

Conclusion.—In closing, Professor Trumbower declared:

"No one has been able to lay down a policy for the distribution of motor vehicle revenues or of raising funds for rural highway purposes which has received country-wide approbation. No such formula, in my opinion, can be devised. Each State is faced with a different set of conditions. It is a general axiom that the motor vehicle revenues, after collection and administration expenses are met, should be applied to highway purposes. No definite rule can be laid down as to how the distribution between State highway systems and local road systems should be made. * * * In the long run motor vehicle operators will find that it will be to their economic benefit if extensive highway improvements are financed through motor vehicle revenues, even though that may result in an increase of license fees and gasoline taxes, rather than go without such improvements and avoid the increased payments."

GENERAL DISCUSSION

In the open discussion, on Mr. Sowers' paper, C. R. Thomas, Jr., M. Am. Soc. C. E., requested further details as to the general method of distributing the tax. Mr. Sowers explained that it would be necessary to have a traffic survey made and to divide the roads into routes depending on the intensity of traffic. The tax is then applied on the basis of gasoline used per mile of highway.

Distribution of Motor Vehicle Revenues in New York State.—Except in New York City, the municipalities receive no part of the taxes collected by the State for highway purposes, according to George H. Norton, M. Am. Soc. C. E. A number of years ago, he declared, a study of the situation in Buffalo, N. Y., revealed that:

"If the average vehicle of the city (taking the probable number of days in which it was operated), in traveling through the city by improved streets, paved streets, and better pavements, could save 10 min. per day in time, that would be saving the vehicle owner $7 000 to $8 000 per year."

He stated his belief that, if the average machine operator could be made to see this economic advantage of better streets, he would be willing to pay the added amount necessary.

In a letter to Mr. Sowers, Executive Secretary Alsdorf, of the Ohio Good Roads Federation, defended the use of gasoline taxes on State highway work. His comment was that:

"This form of a tax as enacted by the Legislatures of the various States can only be regarded as a State tax for State purposes, and in many States the distribution of it to other political subdivisions would be entirely unconstitutional. The question has never come before the State Supreme Court of Ohio, so is unanswered in so far as we are concerned. However, there are two cases that have been passed upon by the Supreme Court in which it has been held that a county cannot levy a tax and expend the money for State purposes. We, therefore, hold a warning against presenting the other side of the problem. It might be found that Ohio would only levy a State tax for State purposes without any distribution to cities or other political subdivisions. At least, it

should be remembered that a State tax levied by the Legislature of the State is primarily for State purposes; hence, neither the gas tax nor the motor vehicle licenses can be regarded as a 'pie-cutting' proposition."

Secretary Alsdorf emphasized the fact that the license fee and gas tax method is a substitute for the old-time method of taxing property. To acquire enough money for road improvements in Ohio would require a property tax of 3 to 4 mills, he declared.

The problem is to determine the most equitable distribution of costs for public improvements.

"Rural folk are just as fair, or even more so, than those from the cities, in working out the solution of any State question. The State Highway System is, and has been, regarded as a State utility to be developed and cared for by a method of State taxation in which the same rate applies to the citizens of each city and county. An aggregation of citizens living in any one community does not relieve them from the responsibility of paying the tax; neither does it deny to them any of the privileges coming from the expenditure of that tax."

The most serious bar to efficient handling of highway traffic, according to A. R. Hirst, M. Am. Soc. C. E., occurs in urban communities rather than in the rural districts. The property owners have been taxed as much as they can stand for highway improvements. On the other hand:

"The motor vehicle owner is paying about 7% of his cost of operation for the construction and maintenance of the roadbed on which he runs, and it certainly is not enough to go around."

The result is sometimes an inconsistent distribution of costs. The City of Milwaukee is wonderfully well governed, but for about twenty years it has done practically nothing to facilitate through traffic, because it has not seemed fair to impose the cost on the property owners.

Mr. Hirst stated his belief that the problem would not be solved until the principle of collecting tolls was re-established. In his own words:

"There is no great consistency, as I see it, in building great bridges and great tunnels (and I think great elevateds are coming in all our major cities) and paying for them by general taxation of property, when approaches are made possible and are paid for by an entirely different kind of taxation. I do not believe * * * in thinking of toll bridges and toll roads as a curse. I personally believe they are the only answer to the problem of the cities in providing means of access and egress from the cities, that will really unleash the latent power that we have in these 25 000 000 or 30 000 000 motor vehicles."

* * * * * * *

"We have got, in my opinion, to come to a gas tax as high as probably 10 cents per gal. if the American people are going to start out to pay the whole cost of the improvements which must be made both in the rural districts and the urban area, in order to turn loose the motor vehicles which we own."

Problems in Legislation.—Need of being prepared to compromise in order to insure the success of a bill before the Legislature, was stressed by Darwin W. Townsend, M. Am. Soc. C. E. One objection that has been raised, in the Legislature, to the gasoline tax was that the use of farm tractors was made to pay for highway improvements. The injustice done is not great, according to Mr. Townsend. The first gasoline law in Wisconsin was vetoed by the Governor ostensibly because it did not return anything to the local communities. A

difficulty that arose at another time concerned the personal property tax on automobiles. The valuation was assessed on May 1 and collected in January following. By that time many of the cars would be discarded, and the tax would be difficult to collect. The proposed remedy is to withhold new licenses until the applicant shows receipt for his personal property tax. Another proposal is to,

"Increase the gasoline tax by one cent, exempt the motor vehicles from a personal property tax proposition, and return this one cent gasoline tax for local units to improve local streets and highways. It does not seem very objectionable because it is a highway tax, and it has reasonableness about it."

Roads and Streets as Parts of a Co-Ordinated Highway System.—This was the ideal presented by C. C. Wiley, M. Am. Soc. C. E. The present situation is due to the fact that:

"The American people have been taught to think the street was one thing and the rural road something else. Naturally, the city started improvements by first writing up some laws, and so we started to build our streets by special assessment. Then the motor vehicle came and we wanted to build our country roads, so the development of funds swung to the rural road and * * * there is not enough money for the rural roads to keep up with the rural road needs. So, boiled down, each unit with any jurisdiction over any public highway is scrambling for every cent it can get.

"The State needs every cent of money it can get, so it hangs on to the gas tax with all ten fingers. The county cannot raise enough money with present limitations, so it wants some of the gas tax. The city has not been able to do anything, so it is trying to get hold of some of the gas tax. Answer: Try to get them together."

CLOSING DISCUSSION

Mr. Sowers, in closing the discussion, called attention to the need of modifying the claim that motor vehicle taxes had increased about 10% in a very short term of years. It seemed not fair to the average passenger car operator. In his own words:

"Has not the motor bus and the motor freight train development in the past few years brought about a larger consumption of license fees and gasoline taxes than the passenger car? That is, the motor bus is paying a much higher tax and the passenger car owner has not had the proportionate increase given him.

"The city dwellers are the principal users of the roads outside the municipalities. That is very true in Ohio, but I do not think it is fair for the city owner of real and personal property to have to provide the wide, heavy pavements in the city for the benefit of the motor buses and the motorists in general. The motorists of a city should not only provide the roads outside the municipality, but they should provide the pavements inside the city and not charge it up against the taxpayers."

Referring to the situation in Ohio, he said:

"It would be interesting to watch the development of the recent law in Ohio which makes the State roster of cities a part of the State Highway System and provides so much for city streets added each year to the State Highway System. Attention has already been called to the wonderful marking system of the

cities of Ohio, because the law permits the marking of the city streets without having to have the permission of anybody. It will be interesting to see if the State Highway Department will be willing to allot a proportion of the State funds to the construction and maintenance of the cities, for the construction of streets and the widening of roads. I do not know how far the State Department is going to go."

SUPER-HIGHWAY DEVELOPMENT IN THE MILWAUKEE METROPOLITAN AREA

By Joseph A. Stransky,* Esq.

This paper contained an outline of the traffic problem of Milwaukee County and a description of steps being taken to solve it. Widths of main highways have been established by fixing set-back lines to conform with future needs, as planned. The divided roadway design of Blue Mound Road, with a right of way of 120 ft. was described in detail, and the advantages of this type were stated.†

DISCUSSION

COMMENTS ON THE GENERAL SITUATION AT MILWAUKEE

By M. W. Torkelson,‡ M. Am. Soc. C. E.

Every public enterprise is limited to the amount of money available, said Mr. Torkelson, in the opening discussion of Mr. Stransky's paper. In his own words:

"It is easy to know what can and should be done, and difficult to provide the funds to carry out improvements known to be necessary to provide for traffic and which would immediately be productive of increases in the value of abutting real estate, equal to or greater than the cost of the improvement. The local taxing bodies cannot be blamed as they have many problems of which the highway problem is only one. Milwaukee County, Wisconsin, has been more than liberal in the past and while its plans for the future are perhaps not worked out with absolute definiteness so very far ahead, the county is doing as much as it can to make easy the acquirement of ample width rights of way for the roads which it will ultimately develop."

The original settlers in Milwaukee County were pioneers in planning for good roads, and, to-day,

"There are about twelve roads that may be called major routes radiating out of Milwaukee like the spokes of a wheel. Every one of these has been paved with a two-lane road to the County line and beyond for considerable distances. Early in its program the County Board laid out the so-called

* Div. Engr., Wisconsin State Highway Comm., Milwaukee, Wis.

† For the full text of this paper see *Roads and Streets*, August, 1929, p. 271.

‡ Wisconsin Representative, Consoer, Older & Quinlin of Chicago, Madison, Wis.

'County Loop', a road paralleling the County boundaries, about two miles inside the boundary, to afford a connection between these various radial routes. The city is now proposing a similar loop, along the outer city limits, which will afford another cross connection between all these radial routes at a location removed as far as possible from the most congested part of the city. In addition to these there are other roads, most of them being the roads along section and quarter-section lines which run at 1-mile intervals north and south and east and west. The development plan contemplates roads 100 or 120 ft. wide on all section lines, and roads 90-ft. wide on all quarter-section lines. This will provide a network of communication."

The route to Chicago, Ill., through numerous cities along the way, has been built and now has almost the aspects of a long continuous city street. An interior route (U. S. Highway 41), five miles from the Lake shore has also been built and is already overloaded. When this road has been developed to its full width of 160 ft., there are still other roads that can be developed with equal facility.

Commenting on the apparent failure of the Arcadian Avenue Road which was built parallel to Blue Mound Road, Mr. Torkelson stated that, in his opinion:

"This is because of the poor entrances afforded by the Arcadian Avenue Road compared with the Blue Mound Road. The latter route affords a continuous line with easy turns and free of street railways all the way from the down-town district to Waukesha and beyond. The Arcadian Avenue route, on the other hand, has very crooked entrances with several square turns both in Milwaukee and Waukesha. One of these is a left-hand turn, at a congested corner on Wisconsin Avenue, in Milwaukee. Unless a driver gets into the inside lane, he cannot make the turn. Farther on, the road runs for considerable distances on streets carrying street-car lines, so that traffic is hampered by car stops. These hindrances are enough to cause traffic to avoid the route where they occur in favor of the route which is free from them.

"This experience illustrates the importance of proper entrances, because after all, traffic will follow 'lines of least resistance'. Often important highways enter a city through a maze of narrow crooked streets. No greater improvement can be made than to widen and straighten these portions of our main routes."

A proposal that has not been widely considered is that of grade separation between two important highways. Granting that the obstacle is cost, Mr. Torkelson argued that they should be planned for the future in the same manner that street widening is now planned by means of set-back lines.

In conclusion, he stated:

"While Milwaukee County is building a few roads of very great capacity, the plan seems to favor a large number of roads of moderate capacity. This is similar to the plan being followed in the development of the State System. It has to commend it the increased service to local communities, which, after all, provide the bulk of the year-round traffic. The Milwaukee authorities are carrying out their program in a way which is not spectacular, but which is getting results without heavy tax levies or bond issues."

WATERWAYS DIVISION

JULY 11, 1929—10:10 A. M. TO 1:00 P. M.

ENGINEERING FEATURES OF THE WELLAND SHIP CANAL

By Frank E. Sterns,* M. Am. Soc. C. E.

As noted by Mr. Sterns, the Niagara Peninsula in Canada has been the scene of canal construction since as early as 1829. Increasing demand led to reconstruction repeatedly so that the present Welland Ship Canal, the fourth in number, has been designed with the idea of accommodating traffic demands for many years to come.

Dimensions.—The accompanying sketch of Lock No. 2 gives a general idea of the size of these structures. It will be noted that the usable dimensions are approximately 80 by 820 ft. in plan, and 30 ft. in depth on the sill platforms. For the canal proper, the present minimum depth is being set at 25 ft., with the idea of future dredging to 30 ft. as required. To avoid future expensive excavation, sections of the present canal in rock are being cleared to a depth of 27½ ft. The remaining reaches in earth will be dredged to the additional depth as required.

As to lateral dimensions, Mr. Sterns explained, "Where the rock surface is near or above the normal water level the prism is 220 ft. wide with vertical sides. In earth, side slopes are 2:1 and the bottom width is 200 ft. at 25-ft. depth."

Number and Location of Locks.—Two conflicting requirements operate in determining the general features of the lock. For instance,

"In order to reduce the time required for a ship to pass through the canal it is desirable to use as small a number of locks as possible by making the lift of each lock as great as practicable. On the other hand, in order to reduce the quantity of water used in locking and for the feed required to regulate the water levels of the reaches between the locks it is desirable to use locks of moderate lift."

By making the lift approximately uniform for all locks, it was possible to keep this to a minimum and, at the same time, make the gate and other details more or less standard.

Still another feature affected lock location, namely, the possibility of utilizing the sites for the location of bridges near the upper or lower gates. In this way, the delay to passage of steamers as well as land traffic could be combined to create the minimum of disturbance.

* Designing Engr., Welland Ship Canal, St. Catharines, Ont., Canada.

From these and other considerations, the total lift of 325.5 ft. between Lakes Ontario and Erie was divided among seven locks, giving an average lift of 46.5 ft. In accordance with the natural terrain, all these locks are fairly near the north, or Lake Ontario, end. Intervals between the lower four locks are more or less uniform at from 1¼ to 2¾ miles. Then come three locks in a single flight (Locks Nos. 4, 5, and 6) and finally, ½ mile farther on, Lock No. 7, which brings the canal to the summit level, 543.0 ft. above sea level.

The three first and the last are single locks. However (quoting Mr. Sterns),

"To avoid the necessity of a ship having to wait at the flight locks until another proceeding in the opposite direction has been locked through the three locks, twin flights have been built so that ships can follow each other closely up one flight or down the other."

The summit level of the canal will be at about the low-water level of Lake Erie. To provide against the difference of elevation when the lake level is above its minimum, a single guard-lock has been placed near the upper, or Lake Erie, end of the canal. It will provide a maximum lift of 12 ft., or an average of about 3 or 4 ft. In order to accommodate several ships at one time, its usable length has been made 1 355 ft.

Filling Culverts.—General features of the devices for filling the locks will be apparent from the sketch. The main culverts were designed to fill or empty the locks in 8 min., or at a maximum rate of 8 ft. per min. The lateral culverts, 30 ft. on centers, have been given a capacity 50% greater than the main culverts.

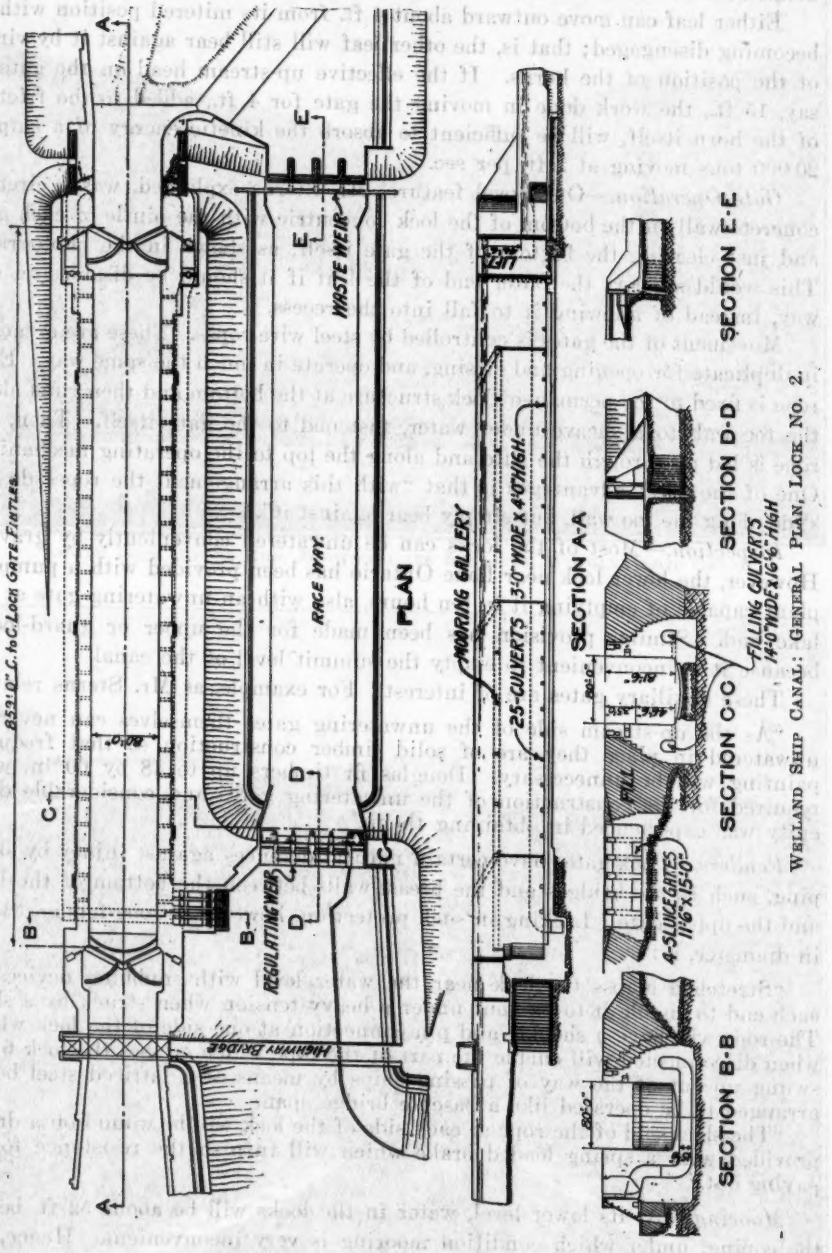
Valves.—Taintor valves were adopted as the most convenient for the conditions of the Welland Canal. Two of these valves are placed alongside each other for each culvert at the upper and lower ends of the lock. Mr. Sterns explained the design as follows:

"To suit the different conditions obtaining at valves in different locations, some valves are operated by means of rigid struts and others by means of wire ropes. Each valve has its own operating machine driven by a 13-h.p., squirrel-cage induction motor. A slip friction is provided in the gear train which will slip and prevent any part being broken should the valve be stopped in mid-travel by any obstruction. The motor is stopped automatically when the valve reaches either end of its travel, by means of a limit switch. In starting, the motor is thrown directly upon the line. The machine will open or close a valve in 45 sec."

Lock-Gates.—Although mitering gates have not been entirely free from accidents in the past, yet this type was adopted for the Welland Canal with certain provisions for safety devices. One such device is the use of guard gates just above and below Locks Nos. 6, 7, and 8, where damage to the main gates might cause a tie-up of the canal for several months.

The gates are formed of a series of horizontal girders sheathed both front and back by steel plates. Enough buoyancy is provided in the lower cells of each gate so that a great deal of weight is taken off the hinge, but not enough to lift the gate from the pintle. The lower gates on the locks are about 82 ft. high and weigh approximately 500 tons. The upper gates are 35 ft. 6 in. high.

Safety Horns.—A second and most valuable device to insure safety of the lock-gates in case of collision with a ship, as described by Mr. Sterns, con-



WELLAND SHIP CANAL: GENERAL PLAN, LOCK No. 2.

sists of "horns". These are an innovation. They are shown in more or less detail both in the sketch and in the photograph of the gates themselves.

Either leaf can move outward about 4 ft. from its mitered position without becoming disengaged; that is, the other leaf will still bear against it by virtue of the position of the horns. If the effective up-stream head on the gate is, say, 15 ft., the work done in moving the gate for 4 ft., added to the friction of the horn itself, will be sufficient to absorb the kinetic energy of a ship of 20 000 tons moving at 2 ft. per sec.

Gate Operation.—One novel feature, Mr. Sterns explained, was a circular concrete wall on the bottom of the lock concentric with the pintle of each gate and just clearing the bottom of the gate itself, as shown in the photograph. This would support the outer end of the leaf if it should be disabled in any way, instead of allowing it to fall into the recess.

Movement of the gates is controlled by steel wire ropes. These are arranged in duplicate for opening and closing, and operate in much the same way. Each rope is fixed to the permanent lock structure at the bottom and then runs along the toe wall to a sheave under water, fastened to the gate itself. Then, the rope is led up through the gate and along the top to the operating mechanism. One of the great advantages is that "with this arrangement the ropes do not slide along the toe wall, but simply bear against it".

Inspection.—Most of the locks can be unwatered conveniently by gravity. However, the lower lock near Lake Ontario has been provided with a pumping plant capable of emptying it in ten hours, also with an unwatering gate at the lake end. Similar provision has been made for the upper or guard-locks, because it is inconvenient to empty the summit level of the canal.

These auxiliary gates are of interest. For example, as Mr. Sterns related,

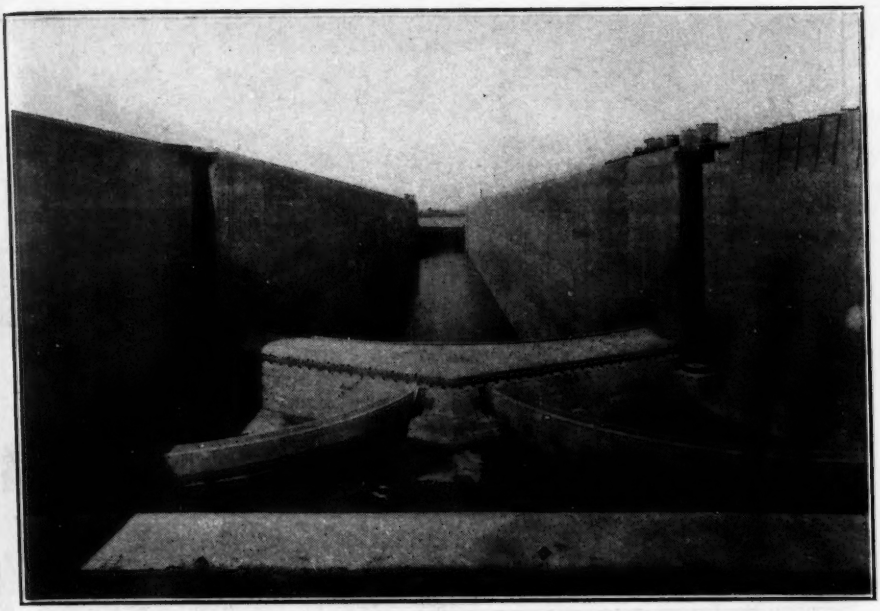
"As the up-stream side of the unwatering gates themselves can never be unwatered in place they are of solid timber construction so that frequent painting will be unnecessary. Douglas fir timbers up to 48 by 60 in. were required for the construction of the unwatering gates and considerable difficulty was experienced in obtaining them."

Fenders.—Lock-gates have certain natural defences against injury by shipping, such as the bridges and the breast-walls between the bottom of the lock and the upper gate. Lacking in such protection, however, a rope fender, 3½ in. in diameter, is:

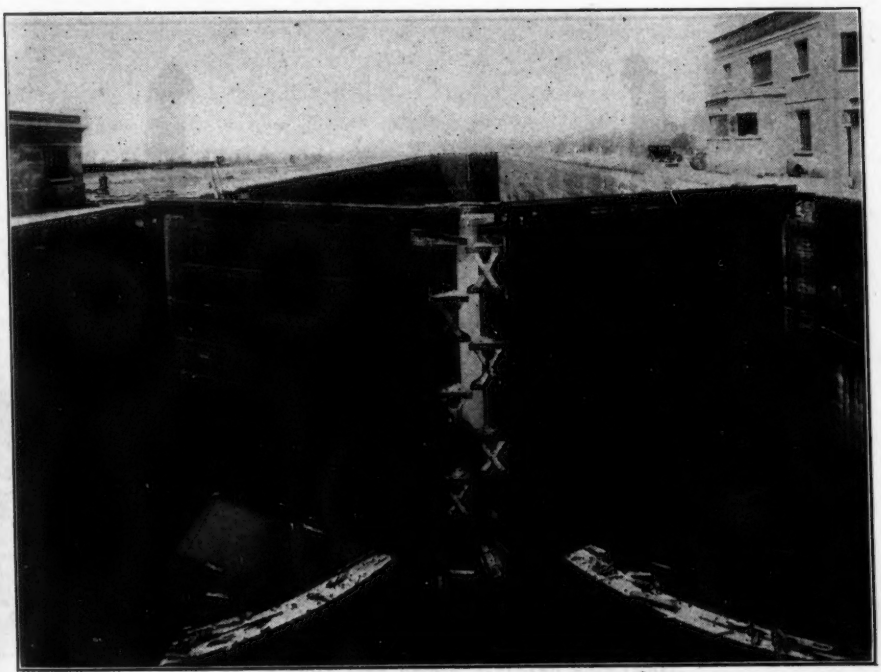
"Stretched across the lock near the water level with snubbing devices at each end to enable it to pay out under a heavy tension when struck by a ship. The rope will have a shackle and pin connection at one side of the lock which when disconnected will enable the part of the rope which crosses the lock to be swung up out of the way of passing ships by means of a latticed steel boom arranged to be operated like a bascule bridge span.

"The slack end of the rope at each side of the lock will be wound on a drum provided with a spring loaded brake which will furnish the resistance to its paying out."

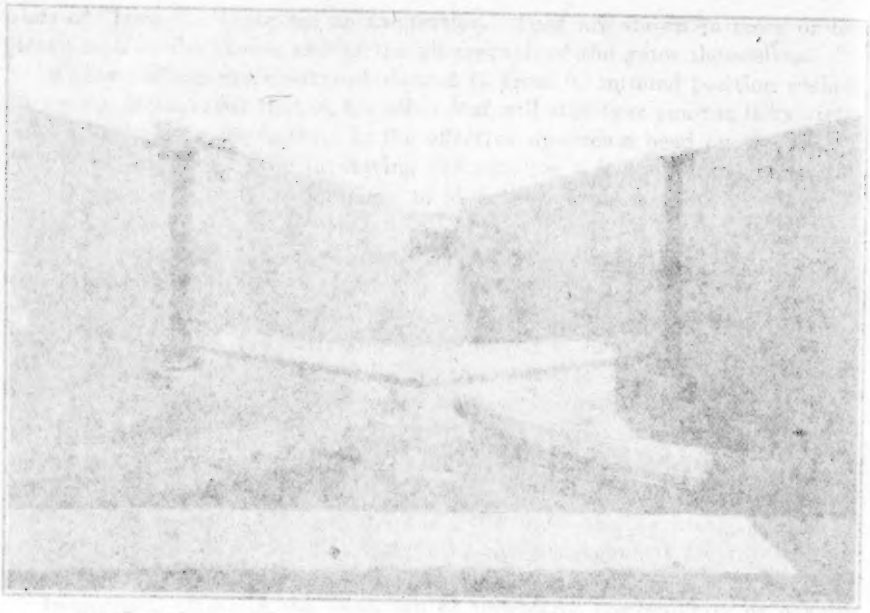
Mooring.—At its lower level, water in the locks will be about 52 ft. below the coping, under which condition mooring is very inconvenient. Hence, an intermediate row of mooring posts has been provided 29 ft. lower down. This is served by a passage from the top leading to openings at the various posts

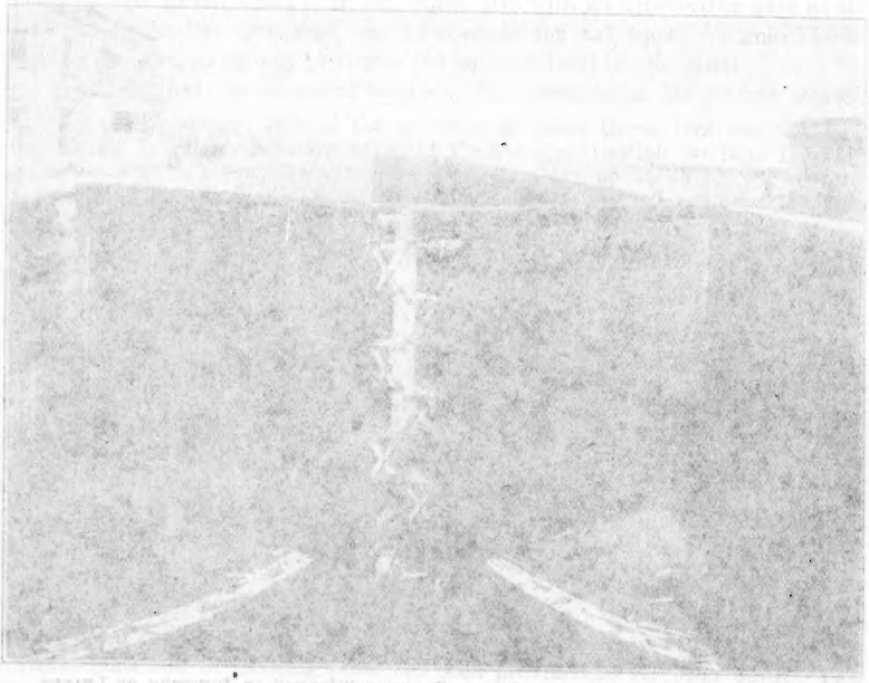


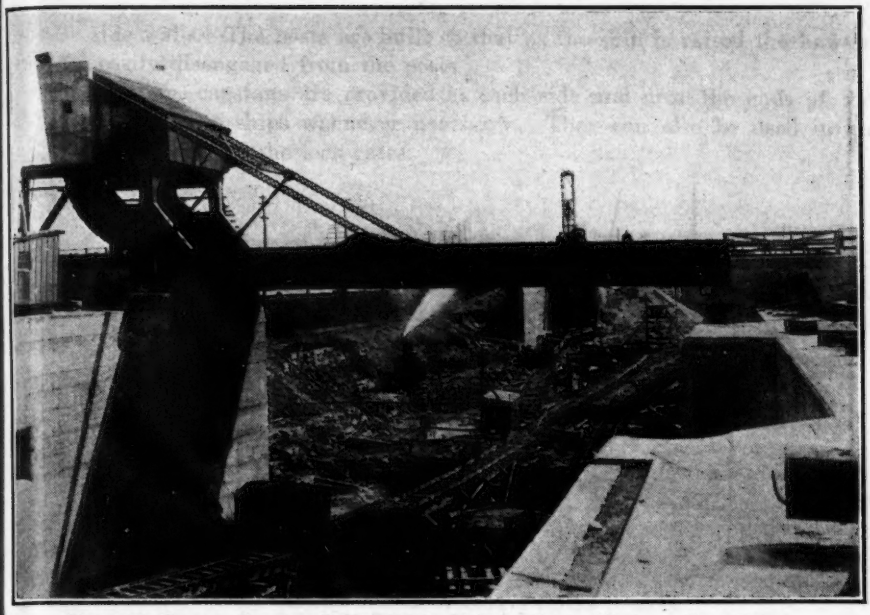
LOWER LOCK, UPPER END, SHOWING GATE SUPPORTS, WELLAND SHIP CANAL.



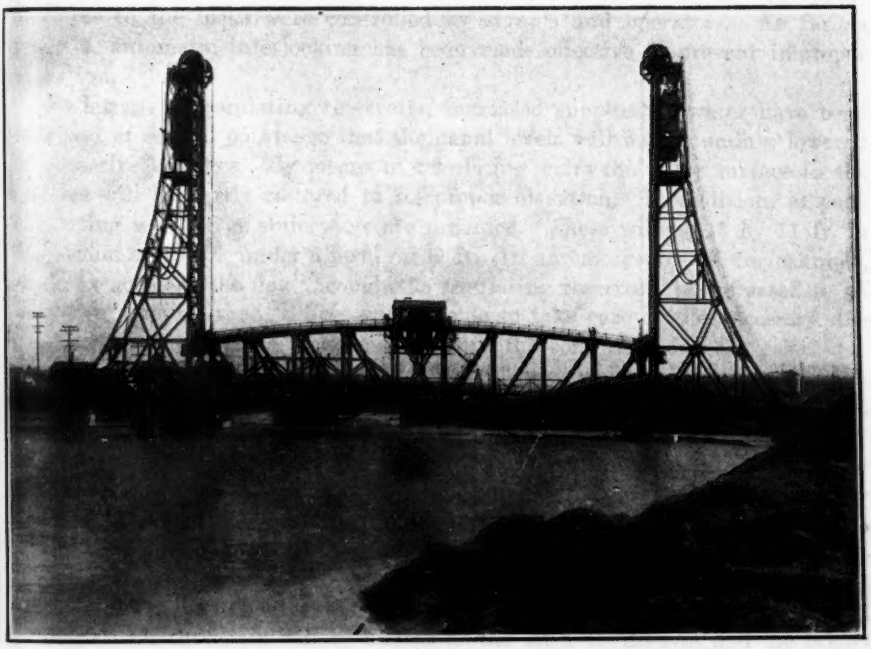
GATES IN PLACE, WELLAND SHIP CANAL, SHOWING "HORNS" AT JUNCTION OF LEAVES.



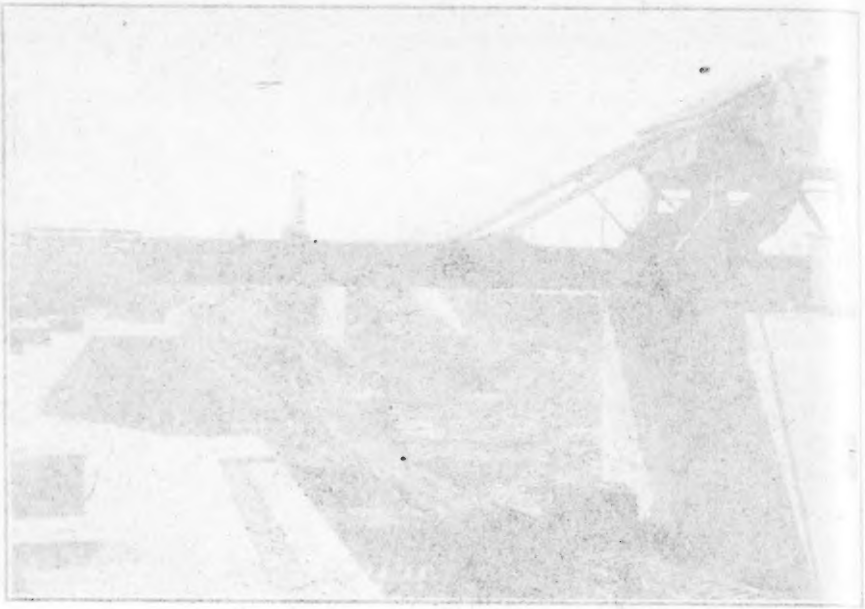




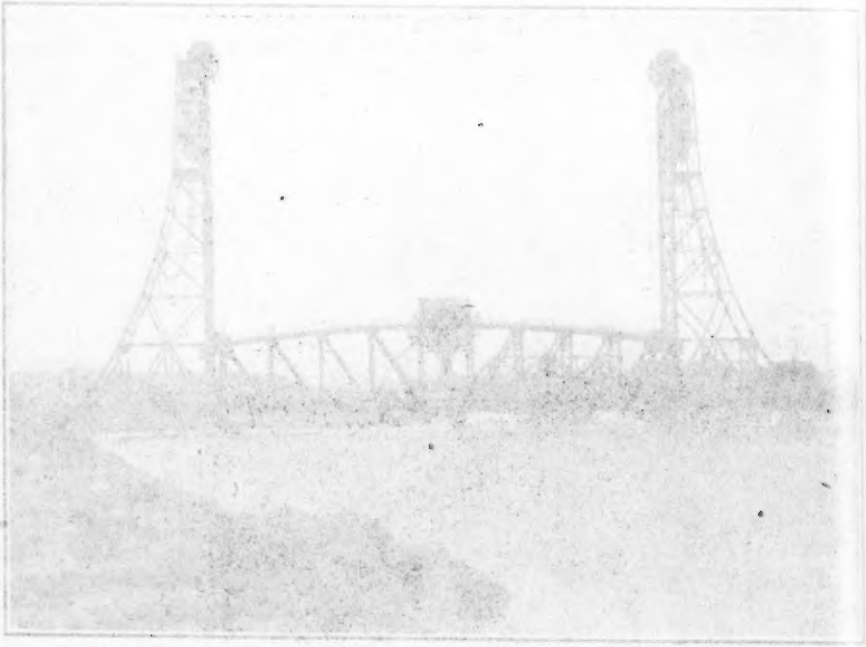
THROUGH GIRDER, ROLLING LIFT BRIDGE, 80-FOOT SPAN, WELLAND SHIP CANAL.



TYPE OF VERTICAL LIFT BRIDGE, WELLAND SHIP CANAL.



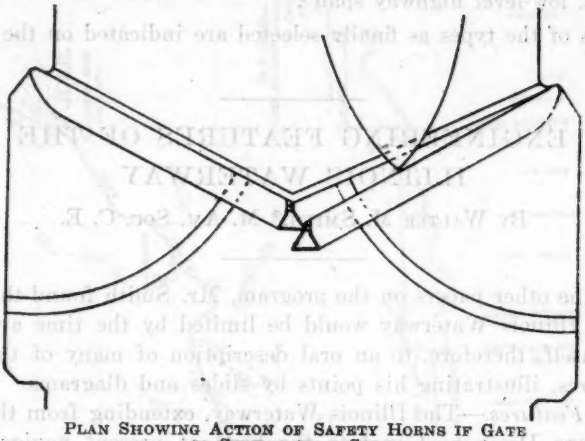
TYPE OF VERTICAL LIFT BRIDGE, BUFFALO RIVER, NEW YORK SHIP CANAL.



TYPE OF VERTICAL LIFT BRIDGE, WELLAND SHIP CANAL.

in the side walls. The posts are built so that as the ship is raised the hawser can be easily disengaged from the posts.

In addition, capstans are provided at each side and near the ends of the locks as an aid to ships whenever necessary. They can also be used in an emergency to operate the lock-gates.



PLAN SHOWING ACTION OF SAFETY HORNS IF GATE IS STRUCK BY A SHIP.

Regulating Works.—In detail, Mr. Sterns showed how the various appurtenances to the locks were controlled by signals and operators. As far as possible, automatic interlocking has been made effective to prevent improper operation.

By means of regulating reservoirs, increased supplies of water have been provided at several points, so that the canal levels will not be unduly lowered by excessive lockages. By means of regulating weirs the water surface in the reaches will be partly restored to its proper elevation. In addition, at each regulating weir, large sluiceways are provided. These will be 15 by 11 ft. in dimension and work under a head of 39 ft. In an emergency, as, for example, when by accident the flow through the regulating reservoirs is increased to an excessive amount, these sluices will be able to take care of the necessary discharge. The number has been made to suit the conditions in each case.

Valves for these weirs are of the Stoney type, which will open automatically. Two sources of power are provided, operating independently, that is, an electric motor controlled by a float-switch and a small hydraulic turbine.

In one instance (Locks Nos. 6 and 7) it was inconvenient to provide the necessary reservoirs so that this pair will be operated in synchronism, as they are only ½ mile apart. As the upper lock is emptied, the lower one will be filled from the common reservoir.

Bridges.—As a measure of the intensity of traffic traversing the canal, it may be noted that about twenty bridges are required to serve highways and railways. Of these, six will be located at the locks themselves and the others will have to span the full 200 ft., or more, of channel "except in two special cases where swing-bridges with a center pier in the middle of the canal are used".

Before adopting particular designs, Mr. Sterns stated, competitive plans were submitted for:

"Bridges of the rolling lift bascule, the heel trunnion bascule, and the vertical lift type for three typical sites, *viz.*, an 80-ft. highway span, a 200-ft. high-level span, carrying highway and single-track electric railway traffic, and a 200-ft. low-level highway span".

Examples of the types as finally selected are indicated on the photographs herewith.

ENGINEERING FEATURES OF THE ILLINOIS WATERWAY

By Walter M. Smith,* M. Am. Soc. C. E.

As with the other papers on the program, Mr. Smith found that the treatment of the Illinois Waterway would be limited by the time available. He confined himself, therefore, to an oral description of many of the important design features, illustrating his points by slides and diagrams.

Location Features.—The Illinois Waterway, extending from the south end of the Chicago Drainage Canal to the head of present navigation on the Illinois River, at Utica, Ill., is about 60 miles long. The alignment and profile are given in the accompanying diagram, showing the various dams creating a series of pools. At only one or two points is the canal separate from the Illinois or Des Plaines Rivers. At these sections, the waterway consists of an independent canal, but otherwise the dredged river itself will be utilized.

Questions of maximum flood flow and the desirable limitations of water height for safety and other matters, determined the design of the several dams, retaining walls, and other structures.

Lock Hydraulics.—On the Illinois Waterway, as Mr. Smith explained, the locks will have usable dimensions of 600 by 110 ft., and lifts varying from 15 to 40 ft. In general, gates of the miter type are used. Details of the Marseilles Lock as shown herewith are more or less typical for the entire canal.

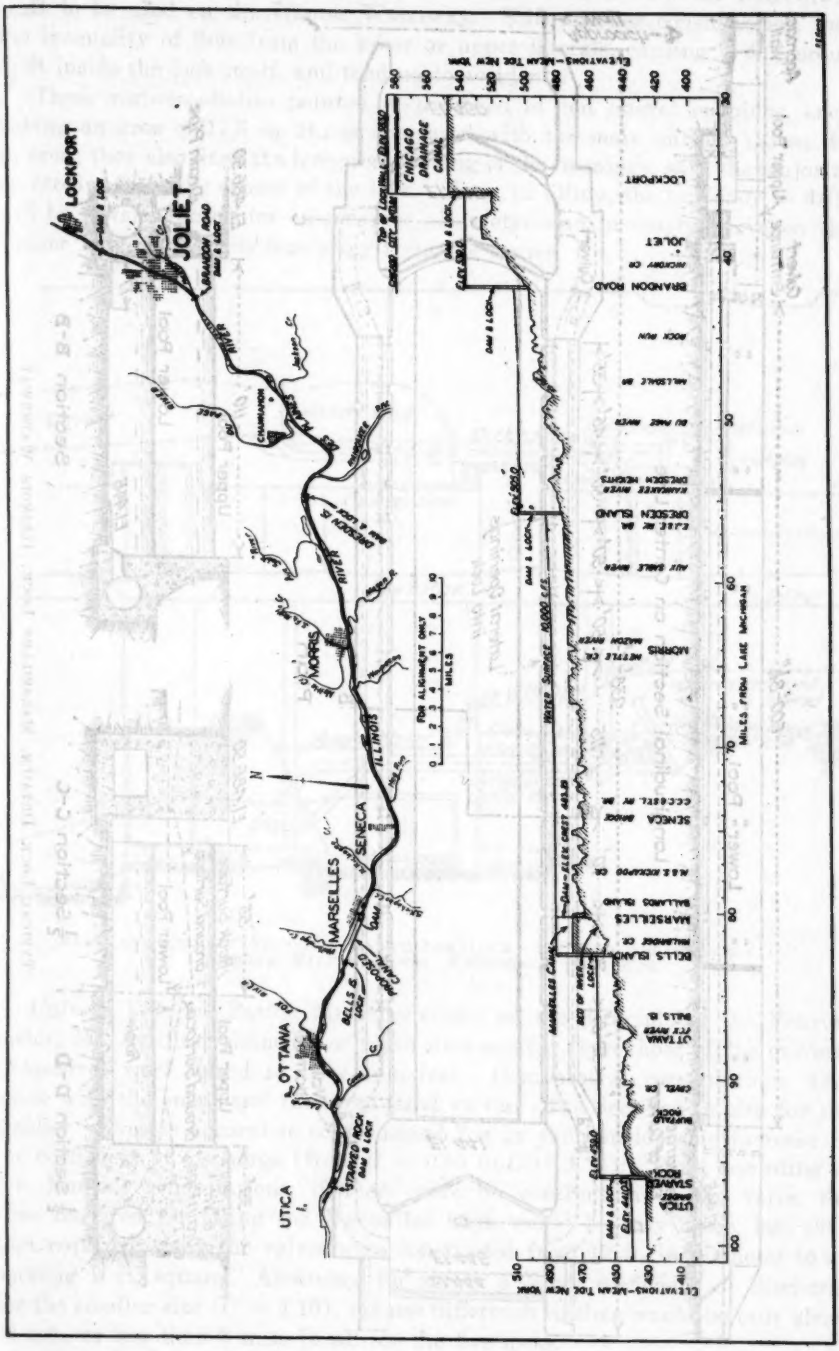
As Mr. Smith explains these hydraulic features:

"The principal requirements of a lock-filling and emptying system, due regard being given to economy, are that it shall permit equalization of levels in a reasonable time, shall not create dangerous water disturbances in the locks or approaches, and shall not allow excessive waste through leakage."

Main culverts, 12 ft. in diameter, were adopted, capable of equalizing levels "in from 7 to 12 min., depending upon the location of the lock and subject to the limitation in equalization of 4 ft. vertically per min."

Considerable study was given to the question of lateral openings, and various typical installations were examined in detail, both as to design and operation. Bottom laterals with vertical openings are very expensive, and,

* Asst. Chf. Engr., Div. of Waterways, State of Illinois, Chicago, Ill.

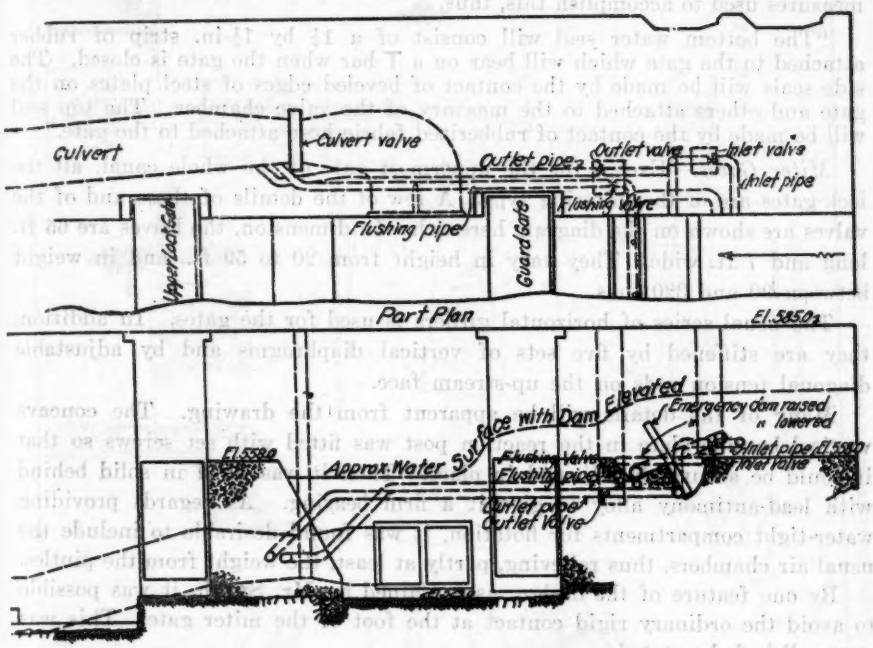


GENERAL PLAN AND PROFILE, ILLINOIS WATERWAY.

TYPICAL LOCK DETAILS, MARSEILLES LOCK, ILLINOIS WATERWAY.

furthermore, seem to offer disadvantages in connection with the light-draft craft to be used on the Illinois Waterway. Still another consideration was the inequality of flow from the lower or upper laterals, causing a dangerous drift inside the lock itself, and tending to accidents.

These various studies pointed to the need of ten lateral openings, each having an area of 17.5 sq. ft., as compared with the main culvert 113 sq. ft. in area; they also fixed the irregular spacing of the openings, with the majority up stream from the center of the lock. Thus, in filling, the tendency to drift will be toward the center—a measure of safety—and in emptying, when the danger from drifting is less, away from the center.



PLAN AND PROFILE THROUGH MARSEILLES LOCK, SHOWING ARRANGEMENT OF CULVERTS, VALVES, GATES, EMERGENCY DAM, ETC.

Culvert Valves.—Basing his calculations on the principle of the Venturi meter, Mr. Smith explained how valve sizes smaller than those of the culverts themselves were found to be economical. Comparative computations were made with the small and the large sized valves. The decrease in size for the smaller valves is somewhat compensated for by the considerable increase in the coefficient of discharge (from $C = 0.85$ to $C = 1.15$). Thus, according to Mr. Smith's computations, if there were no contraction at the valve, the time required for filling the Marseilles Lock would be only 3 sec. less than that required where the valves were constricted from 12 ft. in diameter to an opening 9 ft. square. Assuming for safety a lower coefficient of discharge for the smaller size ($C = 1.10$), the net difference in time would be only about 25 sec., or less than 3 min. in all for the five locks.

To close these 9-ft. openings, valves of 10 ft. by 11 ft. 6 in. will be used. These will be of the wagon-body type, and their main distinctive feature will be the use of roller-bearing wheels. According to Mr. Smith:

"Roller-bearing wheels possess practically all the advantages and none of the objectionable features of journal-bearing wheels or live rollers and the development in the science of their manufacture permits their use for these valves, as the maximum load per wheel is about 27 000 lb., which is within the safe limit".

Devices were provided to prevent excessive leakage which, it is expected, will not exceed ½ cu. ft. per sec. under a 41-ft. head. He describes the measures used to accomplish this, thus,

"The bottom water seal will consist of a 1¼ by 1½-in. strip of rubber attached to the gate which will bear on a T-bar when the gate is closed. The side seals will be made by the contact of beveled edges of steel plates on the gate and others attached to the masonry of the valve chamber. The top seal will be made by the contact of rubberized fabric hose attached to the gate."

Miter Gates.—Except for the uppermost gate of the whole canal, all the lock-gates are of the mitering type. A few of the details of these and of the valves are shown on the diagram herewith. In dimension, the leaves are 65 ft. long and 7 ft. wide. They vary in height from 20 to 59 ft., and in weight between 90 and 320 tons.

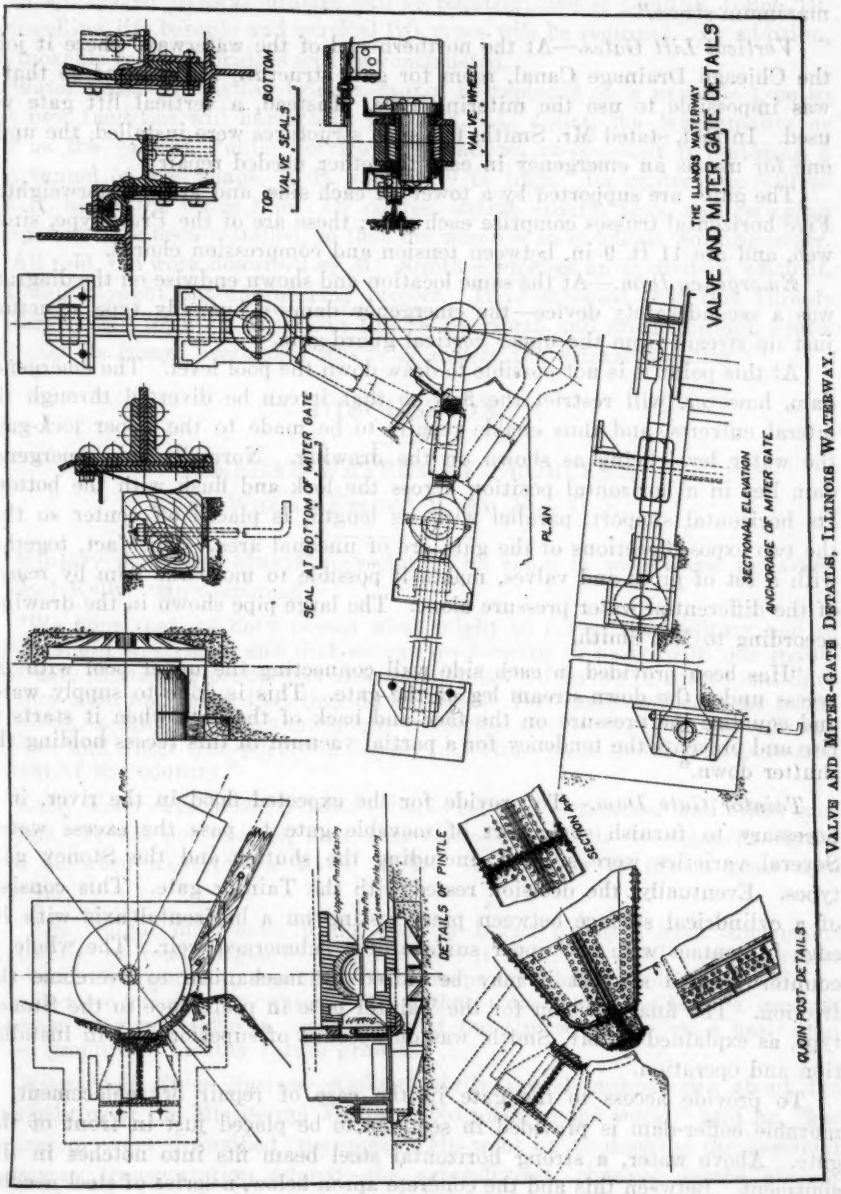
The usual series of horizontal girders is used for the gates. In addition, they are stiffened by five sets of vertical diaphragms and by adjustable diagonal tension rods on the up-stream face.

Many of the details will be apparent from the drawing. The concave vertical bearing-plate in the reaction post was fitted with set screws so that it could be accurately adjusted in place. Then it was filled in solid behind with lead-antimony alloy to give it a firm bearing. As regards providing water-tight compartments for flotation, it was found desirable to include the usual air chambers, thus relieving, partly at least, the weight from the pintles.

By one feature of the design, as explained by Mr. Smith, it was possible to avoid the ordinary rigid contact at the foot of the miter gate. This was accomplished, he stated,

"By placing a metal sealing spring plate on the gate which alone will be in contact with the miter-sill when the gate is closed, and which cannot transmit to the sill more than a part of the pressure due to the water in contact with the spring itself. This permits a more accurate and lighter design of both gate and miter wall and results in decidedly lower costs."

Another interesting feature of the gate design was in the anchorages, also shown in the diagram. Recesses were left in the concrete so that the final adjustment could be made after the gate was in place, and then the adjusting apparatus could be encased in concrete. As shown, two adjusting I-bars are securely anchored into the concrete at about their required position. Each I-bar is in halves, threaded, and connected by an adjusting sleeve. The threads in the bars and sleeves are of slightly different pitch and size for each part, so that by turning the sleeve, a differential change in length of the I-bar results.



VALVE AND MITER-GATE DETAILS, ILLINOIS WATERWAY.

"The advantage of this design over the ordinary turnbuckle is a much finer adjustment per turn and therefore a less force is required, which is an important item as adjustments must be made when the anchor is under maximum stress."

Vertical Lift Gates.—At the northern end of the waterway, where it joins the Chicago Drainage Canal, room for gate structure was limited so that it was impossible to use the mitering type. Instead, a vertical lift gate was used. In fact, stated Mr. Smith, two such structures were installed, the upper one for use as an emergency in case the other needed repair.

The gates are supported by a tower on each side, and are counterweighted. Five horizontal trusses comprise each gate; these are of the Pratt type, single web, and are 11 ft. 9 in. between tension and compression chords.

Emergency Dam.—At the same location and shown endwise on the diagram, was a second safety device—the emergency dam—a butterfly type structure, just up stream from the upper vertical guard-gate.

At this point it is not possible to draw down the pool level. The emergency dam, however, will restrict the flow so that it can be diverted through the lateral culverts, and thus enable repairs to be made to the upper lock-gate, the water level being as shown on the drawing. Normally this emergency dam lies in a horizontal position across the lock and flush with the bottom. Its horizontal support, parallel with its length, is placed off center so that the two exposed sections of the gate are of unequal area. This fact, together with a set of pipes and valves, makes it possible to move the dam by reason of the differential water pressure alone. The large pipe shown in the drawing, according to Mr. Smith,

"Has been provided in each side wall connecting the upper pool with the recess under the down-stream leg of the gate. This is done to supply water and equalize the pressure on the face and back of the gate when it starts to rise and prevents the tendency for a partial vacuum in this recess holding the shutter down."

Taintor Gate Dam.—To provide for the expected flood in the river, it is necessary to furnish some sort of movable gate to pass the excess water. Several varieties were studied, including the shutter and the Stoney gate types. Eventually, the decision rested with the Taintor gate. This consists of a cylindrical surface between piers resting on a horizontal axis with its edge in contact with the upper surface of a submerged weir. The whole is counterweighted so that it may be raised by mechanism to overcome the friction. The final decision for the Taintor gate in preference to the Stoney type, as explained by Mr. Smith, was on account of superior ease in installation and operation.

To provide access to the gate in the case of repair or replacement, a movable coffer-dam is provided in sections to be placed just in front of the gate. Above water, a strong horizontal steel beam fits into notches in the abutment. Between this and the concrete apron below, a series of steel needle-beams may be placed entirely filling the opening. Thus, the space between the coffer-dam and the Taintor gates may be drained of water so that the necessary work on the main gate can be accomplished.

Accessory Structures.—At each site an ice chute is provided, 30 ft. wide. This is a sector dam provided with a pit in which it may be lowered, thus giving a variation of about 7 ft. in the water level.

In all, twelve highway bridges will be required, five of them in Joliet, Ill. Both rolling lift bascule and vertical lift types will be required. In addition, five movable railroad bridges will be constructed.

Water pipes on existing bridges cannot be replaced on a movable type so that new facilities will have to be provided. At Joliet, the Municipality as well as the various Public Service Corporations, co-operated in building a pipe tunnel of oval shape, 10 ft. wide by 9 ft. high. Its center line will be 38.5 ft. below the water line. Of course, shafts, sumps, fans, and pumping equipment have been installed, so that the whole is in excellent working order.

All told, the work described by Mr. Smith comprises an up-to-date, efficient, and well thought out engineering project. It is expected that this Illinois Waterway will form an important link in the north and south through route, and that its future usefulness will fully justify the extensive outlay.

DISCUSSION

GENERAL WATERWAY PROBLEMS

By William Kelly,* M. Am. Soc. C. E.

Military men have always appreciated the value of waterways, remarked Colonel Kelly. He continued:

"We hope that we have passed what might be called the military age in which might was right, and that we can go forward in peace with our industrial age, increasing production and the standard of living, until all can have all they need and much that they do not need. But cheap and efficient transportation is fully as important to our industrial welfare as it was to military success, and water transportation has an important place in the transportation system of the country."

Early waterways were far from reliable because of seasonal and other conditions. It was not strange, then, that railroads in their development should have absorbed most of the water traffic. As recently as fifteen years ago, however,

"The freight movement of the country began to reach such dimensions that some railroads began to consider that it might be good business to let up on the competition, especially with respect to bulk items that could be moved more cheaply by water. Since that time there has been a gradual increase in river traffic in many parts of the United States on a basis that gives promise of healthy future growth."

Mississippi River System.—Colonel Kelly waxed enthusiastic about the possibilities of the Mississippi Valley. "No place in the world," said he, "has greater or more diversified resources." He went on to describe the excellent waterway transportation offered—the expenditures, channel depths already secured, and the valuable connection with the Illinois State Waterway, provided at an ultimate cost of $25 000 000.

* Col., Corps of Engrs., U. S. A.; Vice-Pres., Buffalo, Niagara and Eastern Power Corporation, Buffalo, N. Y.

Statistics of growth promise a great future for the region, and its waterways. As Colonel Kelly remarked, "In their incomplete state, commerce of more than 50 000 000 tons was carried in 1925 on these waterways with an estimated saving in transportation costs of about $18 000 000."

Canadian Waterways.—Canada also has recognized the advantages of waterways and has taxed itself heavily for these improvements. Meanwhile, many Americans are concerned with the possibility of moving the foot of lake navigation eastward to the lower end of Lake Ontario. According to Colonel Kelly:

"So far as the handling of Canadian grain is concerned, there is some cause for apprehension, for the Dominion Government is now building elevators at the foot of Lake Ontario which will doubtless compete with the elevators in Buffalo. However that may be, it is difficult to see how the great cost of the new Welland Canal can be justified until deep-draft navigation is extended to the ocean. When that comes about, as it surely will, the Welland Canal will take its place as one of the world's great accomplishments."

ACTIVITIES OF WATERWAYS DIVISION

Report on Lock Valves.—Following the completion of the announced program, L. C. Sabin, Chairman of the Waterways Division, opened the meeting to more general discussion.

First, he brought up the question of Division Committees, especially that on Lock Valves. Fortunately, Col. Edward H. Schulz, of this Committee, was present to speak for it. He read a prepared report. On motion, it was voted that this be recognized as the Final Report of the Committee on Lock Valves, to be suggested to the Publication Committee of the Society for printing as a Manual.

Future Endeavors.—As to desirable activities of the Division, Mr. Sabin read letters from Mr. George F. Nicholson and Col. W. P. Wooten, members of the Executive Committee of the Division, containing several pertinent suggestions.

In detail, they enumerated subjects suitable for development by the Division. These included, of course, the larger problems of the vast Mississippi System, namely, economics; flood control; regularization or canalization; movable or fixed dams; dikes *versus* retards; flood relief by by-passes; spillways; reforestation; and relief reservoirs. The Welland and the Nicaragua Canals were also suggested as fruitful sources of study. Other topics of a more general character that were mentioned included piles and pile-driving, and waterway terminals.

In commending the program, Sutton Van Pelt, M. Am. Soc. C. E., spoke especially in favor of the economic trend of thought. He further suggested a general study of coffer-dams, outlining the various questions of maintenance, seepage, pumping, etc., to be covered.

Finally, L. D. Cornish, M. Am. Soc. C. E., suggested that the technical activities of the Division be limited to five large topics, each with an active committee to develop it. As an added possible subject, he mentioned the important question of lock-gates.

CONSTRUCTION DIVISION—WATERWAYS DIVISION

JOINT MEETING

JULY 11, 1929—2:30 P. M. TO 5:35 P. M.

CONSTRUCTION METHODS ON THE WELLAND SHIP CANAL

By E. G. Cameron,* Esq.

This paper on Welland Canal construction was co-ordinate with a companion paper on design as delivered by Frank E. Sterns, M. Am. Soc. C. E., at the morning session of the Waterways Division. Only the main outline of Mr. Cameron's paper can be noted here.

Contract Work.—The history of this vast project, now almost completed, extends back as far as 1913 when construction was initiated on the Welland Ship Canal. Mr. Cameron explained the reasons governing the Canadian Government's practice of using unit-price contracts, dividing the work into large blocks aggregating $1 000 000 in value, or more, and requiring a 5% deposit by the contractor on the total amount of the contract. As a result, although the unit prices have been uniformly low, "in no case during the whole period of construction has a general contractor or any of his sub-contractors failed to carry through his work in a manner satisfactory to the Department."

Interference of the World War with this program was so disastrous as to force cancellation of the original contracts, the Government taking over the plant at a reasonable cost, less depreciation, based on the amount of the contract actually completed. Beginning again in 1919, the original contractors took up the work on a cost-plus basis, but this did not prove satisfactory so that in 1921 resort was made to the original plan of unit-price contracts.

Minimum prices for day labor are fixed by the Dominion Government. As an indication of the relative wages, Mr. Cameron noted the recent prices varying from 35 cents per hour for common laborers to $1.00 per hour for shovel runners. The total force varied considerably from a minimum during the winter to a maximum of more than 3 000 in the summer months. The largest monthly average was registered in August, 1926, amounting to 3 728 men.

* Prin. Asst. Engr., Canadian Dept. of Railways and Canals, St. Catharines, Ont., Canada.

Cost Distribution.—The apparent total cost of the Ship Canal, according to present estimates, will be about $122 000 000. Of this, earth excavation accounts for 20%, rock excavation and concrete for 15% each, cement for 9%, engineering for 6%, etc. As so much of the work was included in excavation and concrete, Mr. Cameron confined his description largely to these divisions.

Earth Excavation.—In all, about 50 000 000 cu. yd. of earth excavation were involved in the work. The costs of this were as low as 20 cents in the pre-war period, but averaged about 45 cents for the whole construction. In the same location and for the same kind of work, prices doubled as the result of the war.

Dragline excavators proved especially valuable in the entire work because of their greater range, both horizontally and vertically. However,

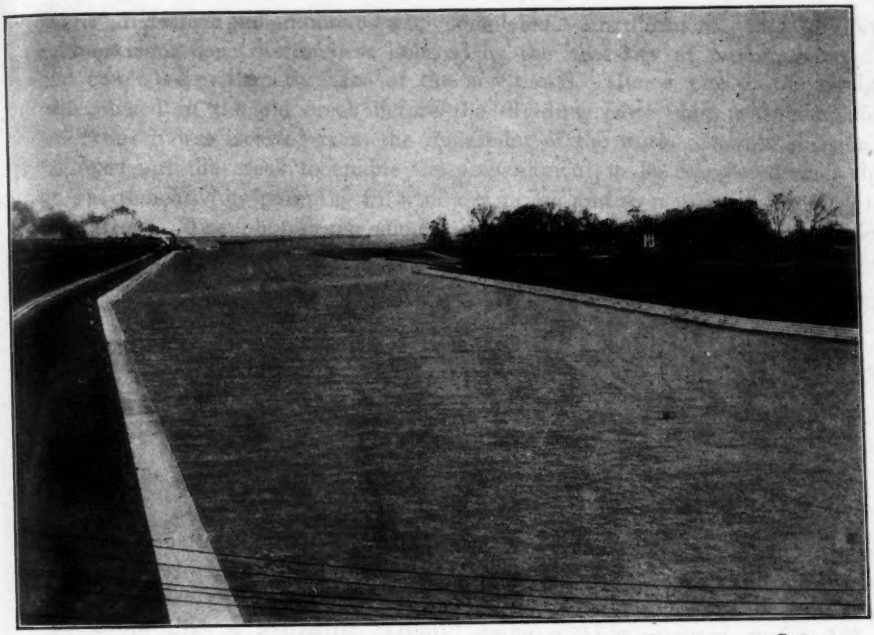
"In many cases a combination operation was carried on, shovels excavating the center core with the draglines finishing up along the side, all loading into standard gauge dump cars."

To aid in disposing of this spoil, the Government built a standard gauge double-track railway 7½ miles long, extending to the artificial harbor at Port Weller on Lake Ontario, at the north end of the canal. While any of the contractor's rolling stock was using this construction railway, it and its crew were entirely under the instructions of the Government Railway Operating Staff.

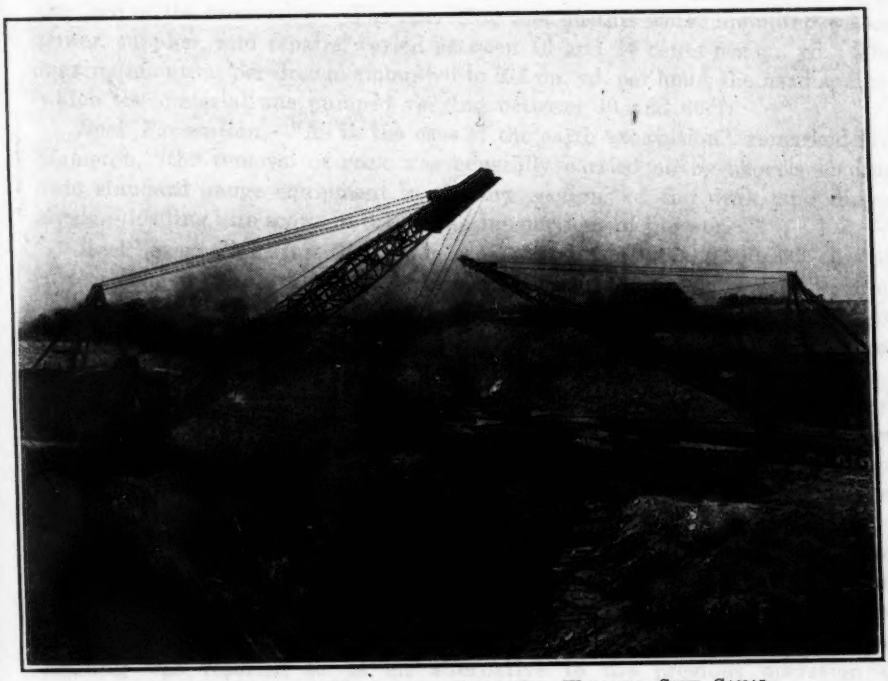
Of the total earth excavation, about 10 000 000 cu. yd. were used in the embankment to form the artificial harbor in Lake Ontario. A further quantity was used for back-filling the locks of other structures; a much larger amount, however, was taken from the summit level, resulting from the widening and deepening of the previous canal. This latter operation was on a dredging basis and much of the material had to be towed to disposal areas in Lake Erie. The length of tow and the delay occasioned by severe weather, prompted the adoption of a combined disposal operation using continuous hydraulic dredges. Because the disposal areas were not conveniently located with respect to the dredging, it was necessary to excavate by a dipper dredge, transport all the material to a point where the hydraulic dredge could conveniently work, and there dump the material, which was then handled to its final dump by the hydraulic dredge. Even with this additional handling, the total cost was reduced from 70½ to 62½ cents per cu. yd.

Preservation of Chippawa Creek.—At one point on the summit level where the new canal adjoins Chippawa Creek for several miles, an interesting problem in excavation procedure developed, as Mr. Cameron explained. The present canal, the new Ship Canal, and the creek occupy separate adjoining locations in that order, as shown in the diagram. The Ship Canal is about 10 ft. above creek level, and thus requires water-tight embankment on the one side. Moreover, at several places it occupies the present location of the creek, so that a new river channel had to be built. In all, about 11 000 000 cu. yd. of excavation were involved.

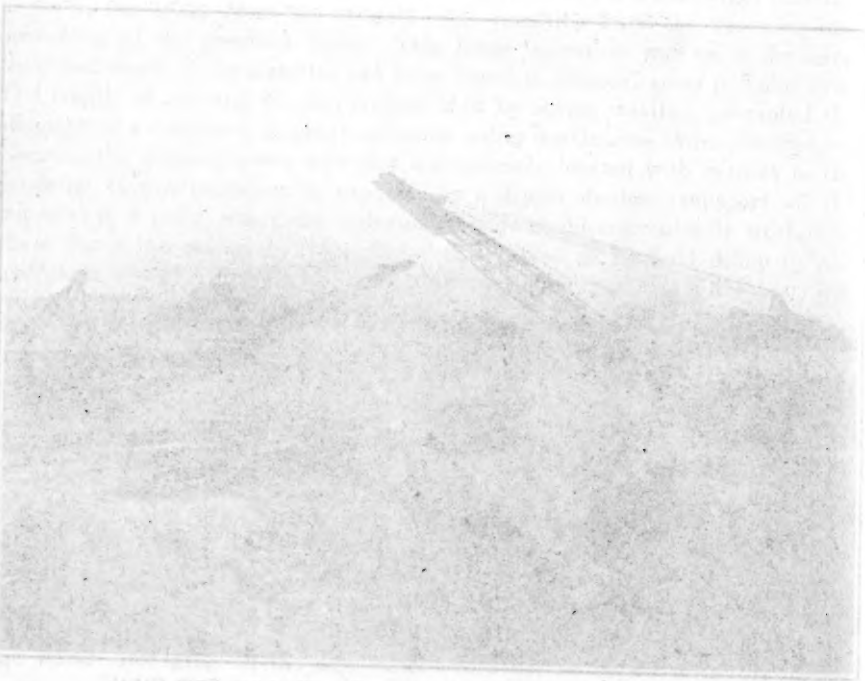
Two hydraulic dredges were used in excavating the creek diversion. Then came the problem of keeping the dredges occupied during the remainder of the work. Dredging on the new canal could not be begun until the water-



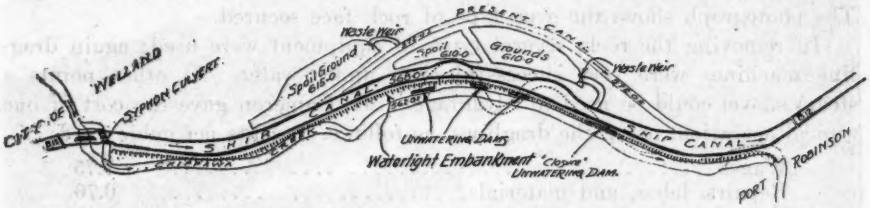
WELLAND SHIP CANAL: PORT WELLER HARBOR AND NORTHERN ENTRANCE TO CANAL.



DRAG-LINE MACHINE WORKING IN LOCK PIT, WELLAND SHIP CANAL.



tight dividing embankment was completed. Furthermore, this dividing embankment construction was delayed by the necessity of pumping out the old creek bed within the area of the new canal. Hence, one of the dredges was placed in the old creek before the dividing earth dam was completed, and thus it was isolated from the remainder of the work. In this position it pumped out the creek to enable the embankment to be completed, and then it was re-floated by pumping into the dry prism and so continued its dredging operations. The photograph shows the dredge at work after these various steps had been taken.



SECTION OF COMPLICATED DREDGING OPERATIONS.

The remainder of the wet excavation was comparatively simple. At some places in which the dredge worked, the opposing bank was quite high, and danger was experienced from the caving due to undercutting of the dredge. To avoid this, a hydraulic "Giant" using a 1½-in. stream, under 125 lb. pressure, was mounted on the front edge of the dredge and used to lower the face of the excavation. The operating cost on this work, including wages, power, supplies, and repairs, varied between 16 and 24 cents per cu. yd. The maximum output per dredge amounted to 215 cu. yd. per hour, the head against which the material was pumped varying between 40 and 60 ft.

Rock Excavation.—"As in the case of the earth excavation", remarked Mr. Cameron, "the removal of rock was generally carried on by shovels loading into standard gauge equipment in the dry sections of the work, and dipper dredges loading into scows in the submarine portions of the work."

Rock excavation for the whole work totaled almost 9 000 000 cu. yd. Prices ranged from a little more than $1 per cu. yd. for dry excavation prior to the war, to $10 per cu. yd. for wet excavation since the war. The major part of this work was accomplished in the latter period, and the cost averaged over the whole amounted to $1.89 per cu. yd.

Excavation for the flight-lock structure involved about 3 000 000 cu. yd. of a good grade material for concrete. Wasting this material would have been quite expensive. Accordingly, the contract provided that it should be crushed. The aggregate thus obtained was provided free to the various contractors needing it for concrete.

Rock cuts for the canal were designed to have vertical sides. To accomplish this, in the early stages of the work before the war, channelers were employed working in 6-ft. lifts; but this was slow as well as expensive. Hence, stated Mr. Cameron, "in resuming work on this section after the war, close drilling was resorted to as an alternative to the previous operation of channeling". Holes for this limiting cut were drilled along the side on

12-in. centers for the full depth of the excavation, but no explosive was used in these holes. Adjacent to this row and within the canal prism, no holes were drilled for a distance equivalent to the depth of excavation. In this way, the holes for shooting were confined to the center part of the prism. At first, 5-ft. lateral spacing was used for these central holes, but later an 8-ft. spacing proved better as regards uniformity of blasted material.

These blasting holes were shot with heavy charges of 70% and 40% dynamite, and when they were exploded, loosened the entire prism. In all cases the rock broke away on the line required and gave an excellent surface. The photograph shows the even type of rock face secured.

In removing the rock, several types of equipment were used; again dragline machines were very successful even under water. At other points a steam shovel could be used to advantage. Mr. Cameron gave the cost of one typical operation, using the draglines, as follows, in cents per cubic yard:

Wages	7.75
Repairs, labor, and materials	0.70
Power	3.41
Oil, waste, sundry supplies	0.47
Cable, 1¾ in. and 1 in.	1.65
Net excavating and loading cost	13.98

For this same locality, the total cost of excavation per cubic yard, was divided among its several parts, thus:

Drilling	$0.1592
Blasting	0.4724
Excavating and loading	0.1398
Transportation	0.1723
Disposal	0.0863
Field operating cost	$1.0300

As stated by Mr. Cameron, "the value of plant and equipment installed for this rock operation was $300 000."

In still another part of the work, using shovels of various capacities between 6 and 1¼ yd., the net excavating and loading costs averaged 35½ cents per cu. yd. The total operating cost was $1.17 per cu. yd. In this instance, the standard equipment was valued at $500 000.

With respect to the blasting operations, Mr. Cameron noted the following interesting facts:

"The average rate of drilling was 22 ft. per hour, based on actual drilling time.

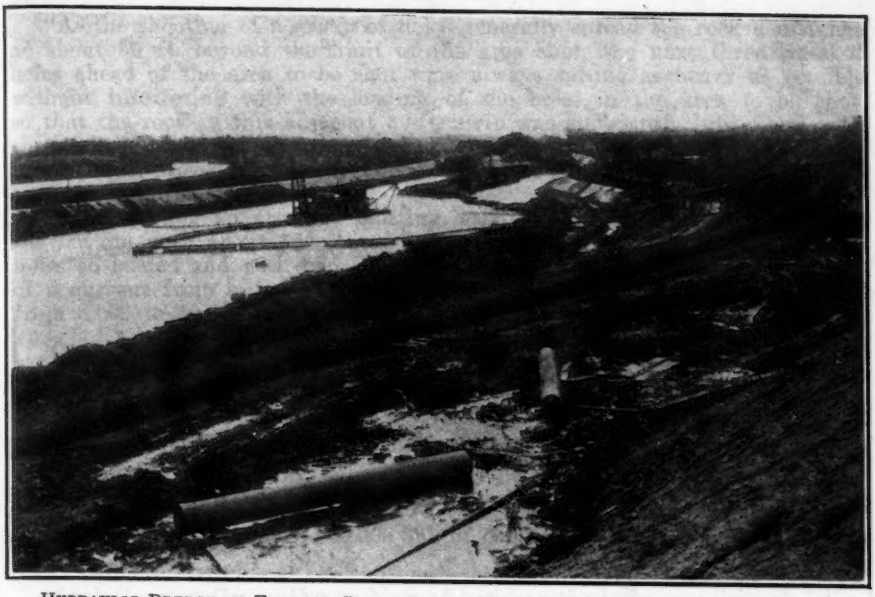
"The average depth of holes was 38 ft. and holes were completed with one set-up of the drills.

"Two-thirds (⅔) of a foot of drilling, including close drilling, was done for one (1) cubic yard of rock removed.

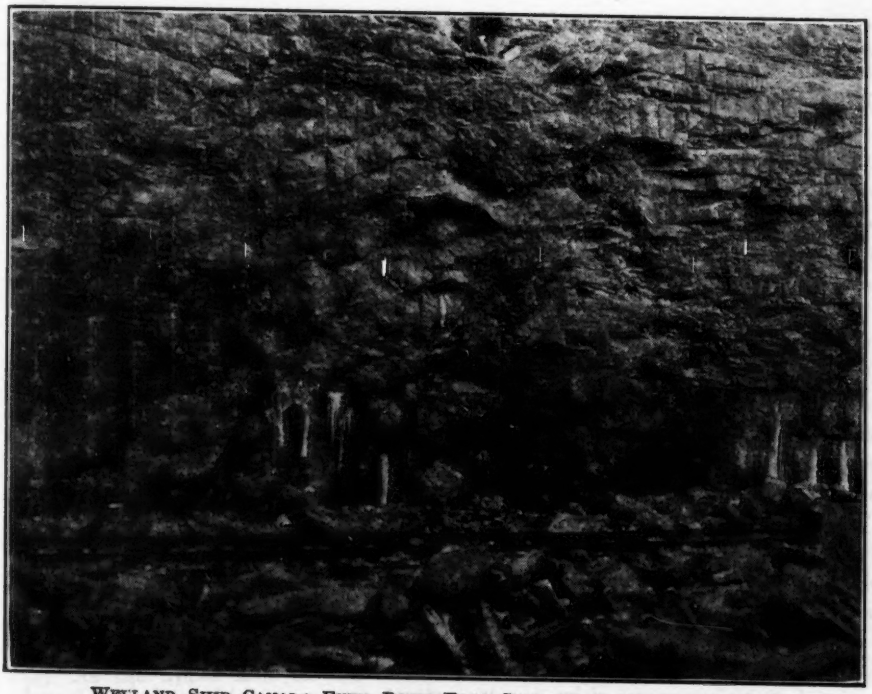
"One and one-half (1½) pounds of dynamite were used in springing and blasting for one (1) cubic yard of rock removed."

* * * * * * * * *

"* * * Before final loading, each hole was independently sprung four times, the first spring using two sticks, and the fourth or last spring fifty-five sticks of 65% dynamite.



HYDRAULIC DREDGE IN FLOODED CANAL PRISM, WELLAND SHIP CANAL, RIVER BEYOND.



WELLAND SHIP CANAL: EVEN ROCK FACE SECURED BY CLOSE DRILLING.

"As the shooting of a group of holes generally spread the rock a distance of about 30 ft. beyond the limit of the area shot, the next three lines of holes ahead of the area to be shot were always sprung as heavy as possible without interfering with the loading of the holes in the area to be shot, so that the rock in this adjacent 30-ft. strip was sufficiently broken up with the main shot that the actual loading and shooting of these three rows of holes never proved necessary, and no hard rock was encountered between areas actually blasted.

"In preparing an area for blasting, each hole in the area was loaded in the bottom with about 100 lb. of 40% dynamite and with from 80 to 100 holes so loaded and with two caps in each hole a shot was fired by the use of a current from an adjacent 220-volt circuit. Each of these shots moved from 8 000 to 10 000 yd. of rock."

Concrete.—The total quantity of concrete used on the Welland Ship Canal amounted to about 3 500 000 cu. yd., of which about 3 250 000 cu. yd. were paid for on the unit-price basis. The average cost of this latter was about $5 per cu. yd. During the pre-war period, prices as low as $2.65 per cu. yd. for mass concrete were found; subsequently, however, these increased to a minimum of $4.14 for mass concrete to as high as $15.00 per cu. yd. for concrete in bridge cribs. For the 4 500 000 bbl. of cement the average price was about $2.15 per bbl.

Lock Construction.—The problem of building the locks was thus visualized by Mr. Cameron:

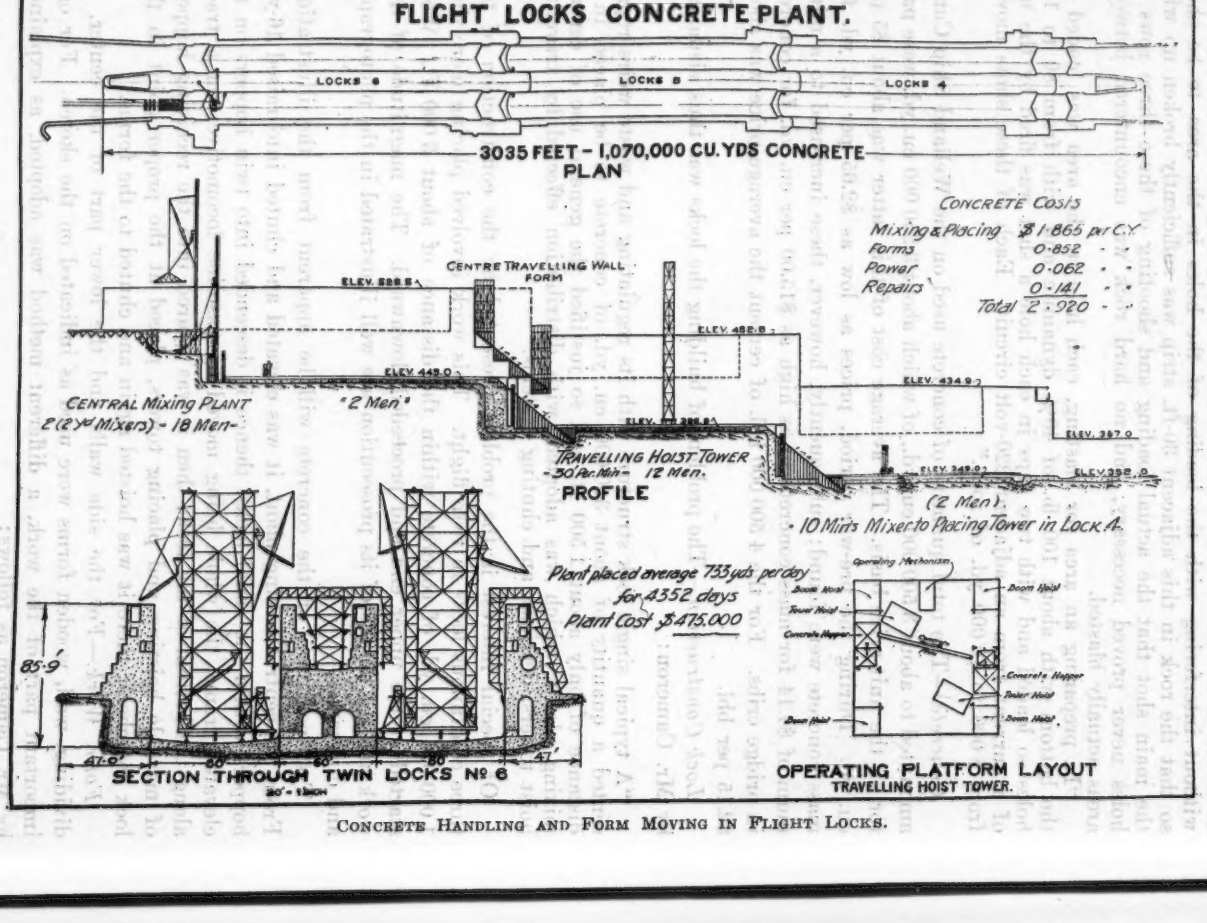
"A typical single lock structure with its regulating and waste weirs represented a quantity of about 360 000 cu. yd. of concrete to be placed in a distance of only about 1 500 ft. and so justified the general use of central mixing plants, which was adopted, with distribution effected by traveling hoist towers, derricks, and chuting systems."

Of special interest is the problem presented by the construction of the three continuous locks in twin flight. This work involved placing more than 1 000 000 cu. yd. of concrete within the distance of about 3 000 ft. Work started at the upper end and proceeded downward. The magnitude of this work and the details of its prosecution are well illustrated in the photographs and diagrams.

Transportation of the concrete will be apparent from the illustration. From the central mixing plant, it was elevated and chuted into raised 16-yd. hoppers within the canal locks, thence it descended into twin hoppers on an elevated frame, the whole being moved by gasoline locomotives on a track along the bottom of the lock; then it was poured into the receiving hoppers of movable hoisting and placing towers, placed at the proper point in the lock chambers; there it was hoisted again and chuted to the forms.

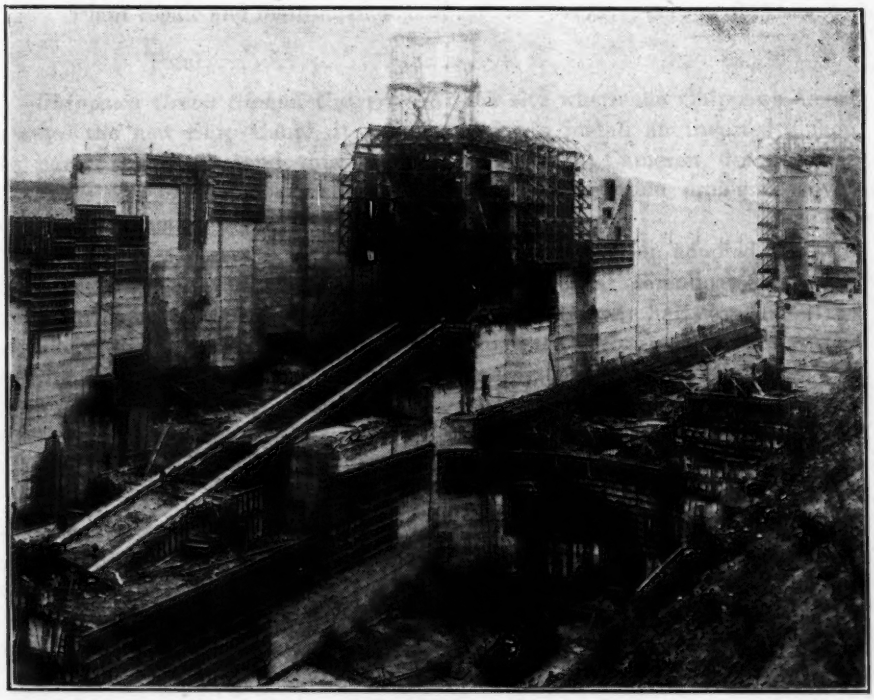
Form Work.—For the side walls and the lower part of the center, or dividing, wall, wooden forms were used as indicated on the sketch. For one important part of the work, a different method was adopted, as explained by Mr. Cameron as follows:

"As the upper half of the center wall, for 700 ft. of the lock chamber length, consists of two separate gravity sections, with a space of 24 ft. between their bases (to effect economy in concrete), and contains the longitudinal

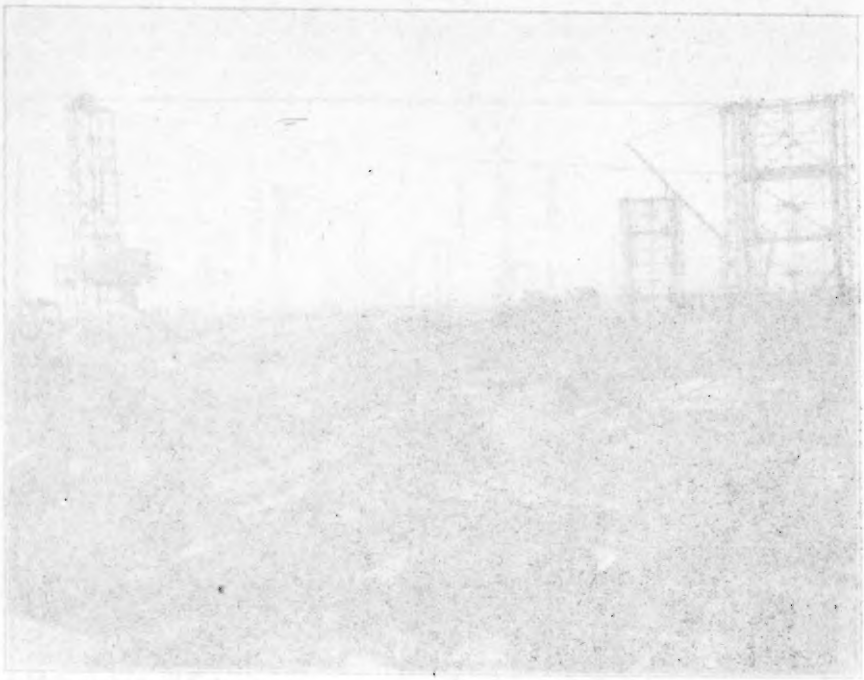


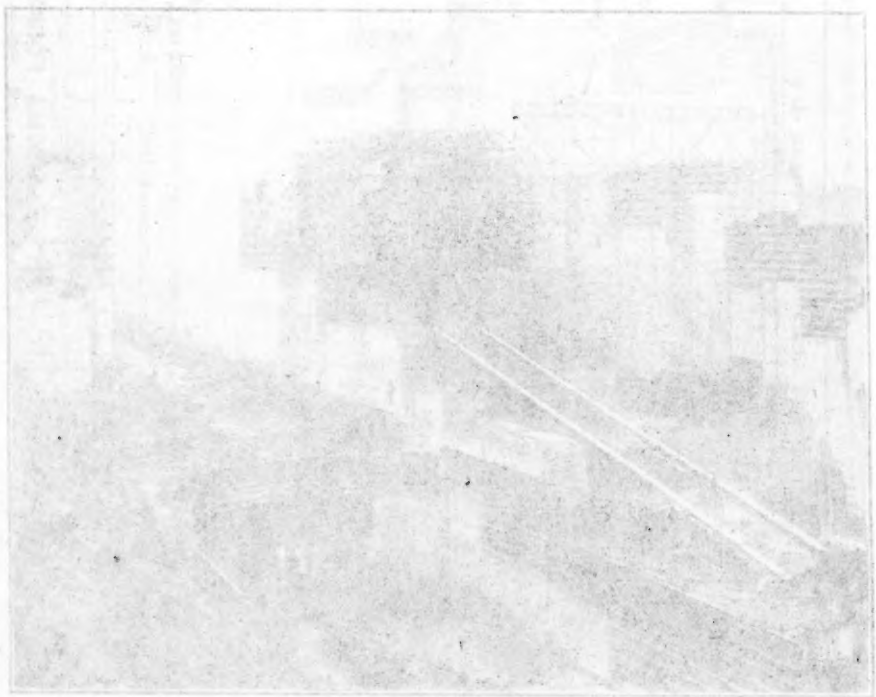
CONCRETE HANDLING AND FORM MOVING IN FLIGHT LOCKS.

TWIN LOCK CONSTRUCTION, SHOWING CONCRETE HANDLING, WELLAND SHIP CANAL.



WELLAND SHIP CANAL: MOVING CENTER WALL FORM FROM UPPER TO MIDDLE LOCK OF TWIN FLIGHT.





mooring passage, the cable tunnel, and the drainage tunnel, all involving extensive form work, the use of a traveling steel form for this upper half of the center wall was adopted.

"Accordingly, a structural steel T-shaped frame, 60 ft. long, was provided to carry the wooden forms outlining the two adjacent gravity walls as a unit."

This center form weighed 300 tons, and required about four days for filling with concrete. A somewhat similar form was used for the upper part of the side walls. However, these steel forms, Mr. Cameron stated,

"Did not prove, in use, the success that was anticipated of them. Their handling and setting up was expensive, but the greatest expense attached itself to the transfer of these form units from one lock to the next."

This transfer or lowering, was an interesting operation, as shown by the illustration. The actual rate of movement for the form itself was less than 1 ft. per min., so that the entire operation took 4 hours. The first attempt, from the upper to the middle lock, was entirely successful, but on the final movement from the middle to the lower lock, one of the shackles gave way and the whole form was dumped into the lower lock chamber. It was not replaced; wood forms were used instead.

"The cost per cubic yard of the concrete in the flight lock structure, exclusive of overhead and plant rental, was as follows:

"Mixing and Placing	Labor	$0.490
	Materials	1.375
Forms	Labor	0.577
	Materials	0.275
Power		0.062
Plant repair and maintenance		0.141
Total		$2.920"

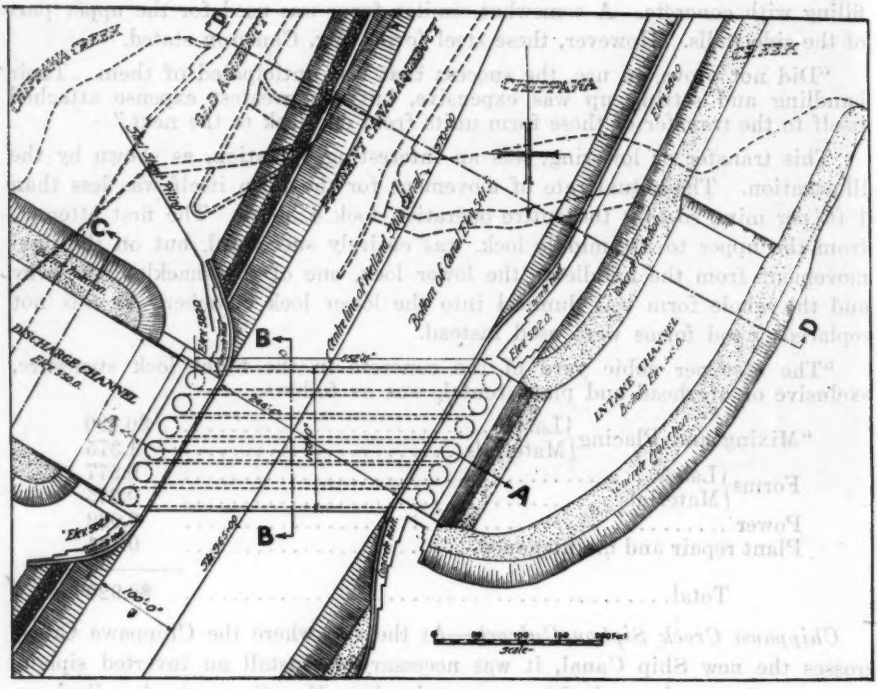
Chippawa Creek Siphon Culvert.—At the site where the Chippawa Creek crosses the new Ship Canal, it was necessary to install an inverted siphon to carry the creek, and this presented what Mr. Cameron described as "perhaps one of the most interesting general construction problems solved in the construction of the Welland Ship Canal."

The sketches herewith illustrate the general construction adopted. It will be noted that the interference of the present canal complicated matters seriously. As the siphon structure extends approximately half way under the present canal, it was necessary to enclose this area within a coffer-dam. For this purpose a series of twenty-six cells were arranged around the perimeter, each cell formed of steel sheet-piling, some of it 70 ft. in length. The general horizontal dimensions of each cell were 26 ft. lengthwise along the coffer-dam by 36 ft. transverse.

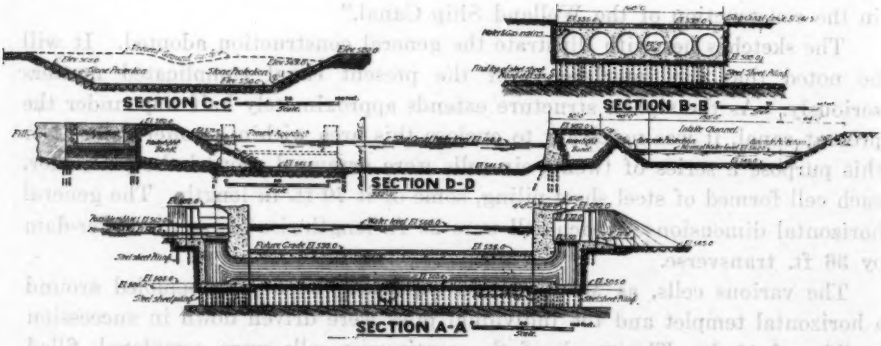
The various cells, as Mr. Cameron explained, were pre-assembled around a horizontal templet and the individual piles were driven down in succession in lifts of 10 ft. Thus each of the continuous cells were completed, filled with hard clay from dry excavation; then the interior water level inside the dam was lowered and the soil dredged to the grade of the Ship Canal prism. Within this coffer-dam actual siphon construction was carried on

in a series of pits covering the whole area, each pit enclosed in steel piling thoroughly braced with wooden timbers.

Construction was carried on consecutively in pits around the perimeter of the coffer-dam and finally the central portion was built within a single long pit.

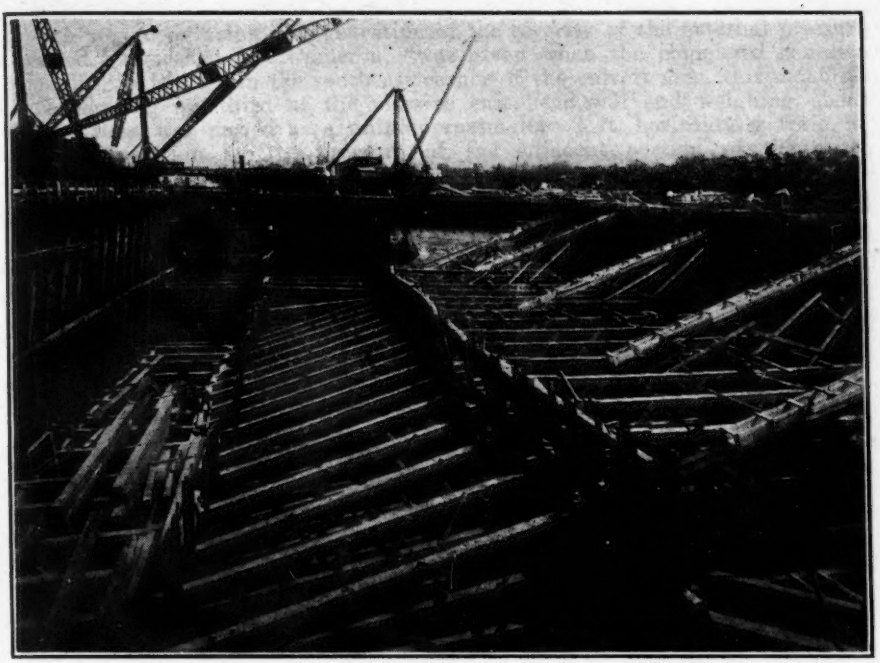


CHIPPAWA CREEK SIPHON—PLAN VIEW.

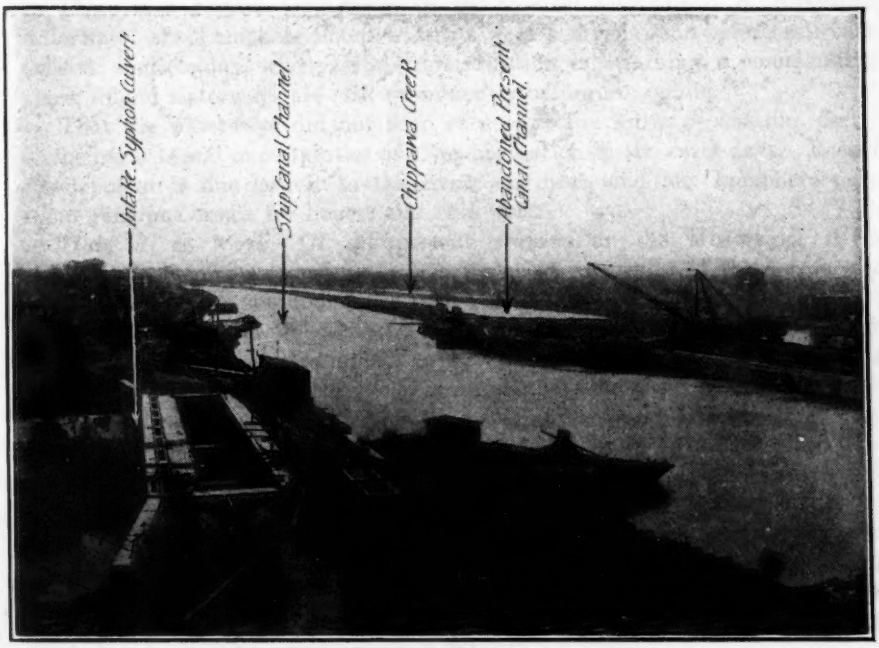


CHIPPAWA CREEK SIPHON—SECTIONAL VIEWS.

Heavy Earth Pressure.—In this work the most serious difficulties were occasioned by the excessive earth pressure and the necessity for extremely heavy timber bracing.



CHIPPAWA CREEK SIPHON: HEAVY TIMBER BRACING TO SUPPORT WEAK SIDE WALLS OF COFFER-DAM.



CHIPPAWA CREEK SIPHON COMPLETED AND IN OPERATION.

"A very convincing demonstration of the severity of the external pressure exerted," remarked Mr. Cameron, "was given when the completed concrete monolith in Pit 'F', in the southeast corner of the culvert area, this monolith incorporating one-third of the massive east head-wall and weighing about 12 000 tons, was moved as a unit approximately 2 ft. horizontally from its original position by the pressure of the adjacent portion of the outer coffer-dam."

The bracing shown in the photograph was required over the longitudinal central pit for the support of one of the side walls which had exhibited weakness.

When the coffer-dam had been removed and the new channel established over the siphon, two years and ten months had elapsed from the original work at this site. Because of its intricacy all details were laid out by the Government engineers and only the selection of plant was left to the discretion of the contractor. The photograph of the finished structure at this point hardly indicates that it was one of the most ticklish parts of the whole Welland Canal construction.

CONSTRUCTION METHODS ON THE OHIO AND MISSOURI RIVERS

By F. E. Lamphere,* M. Am. Soc. C. E.

There is a certain persistence in the interest maintained in American waterways, Mr. Lamphere noted. Canals were a major issue before railroads existed; and, to-day, when aerial transportation is attaining a commanding place, inland waterways are still prominently before the public.

That the waterways did not keep pace with the railways was due partly to the hazards and uncertainties of river navigation in the early days. Recent development is due largely to the Army engineer, and Mr. Lamphere gave them generous credit for honest and able work.

Ohio River Work.—Of the present projects on the Mississippi River System, Mr. Lamphere stated, "by far the most important of these from the construction man's standpoint has been the Ohio, with its tributaries."

The first dam on the Ohio built by the Government and authorized in 1879, was of the movable wicket type, which form is still adhered to and is proving entirely satisfactory. It is unfortunate but true that "pork barrel" legislation had its detrimental effects. Beginning in 1905, however, a comprehensive plan of improvement was studied so that in 1910 the entire Ohio project was adopted by Congress. To-day, after almost twenty years, this whole work is practically completed, at a cost of almost $120 000 000.

General Features, Ohio Dam.—Dams on the Ohio River total 49, varying in length from about 1 500 ft. just below Pittsburgh, Pa., to about 1 mile near Cairo, Ill. The lift in the locks is moderate and varies from 6 to 12 ft., except at Louisville, Ky., where it is considerably more. In all except two

* Constr. Mgr., United Engrs. & Constructors, Inc., Philadelphia, Pa.

instances, the dams are of the movable type, giving free navigation in the high-water season.

In many cases construction has been carried on by Government plant and forces; this was due to the uncertainties of the conditions for work and the large initial expenditure for plant. Five to ten years is required for the work in each instance, at least two years for the lock and three for the dam.

The usual procedure, noted Mr. Lamphere, was,

"To build the lock first, and then the dam in successive stages from the lock across the river to the abutment. The minimum number of sections in which a dam could be built was three. This was governed by the amount of open river which must be available at all times, both for uninterrupted navigation at favorable stages of the river and principally for the passing of flood waters."

During the working season, the question of pumping is a serious one. Mr. Lamphere instanced one piece of work in which it was necessary to pump 40 000 gal. per min. against a head of 40 ft. for a period of several months. Furthermore:

"The practicability of providing coffer-dams that would not be topped was entirely out of the question, on account of cost due to the extreme height of flood stages. Therefore, the coffer-dams were built so that they could safely pass through any flood."

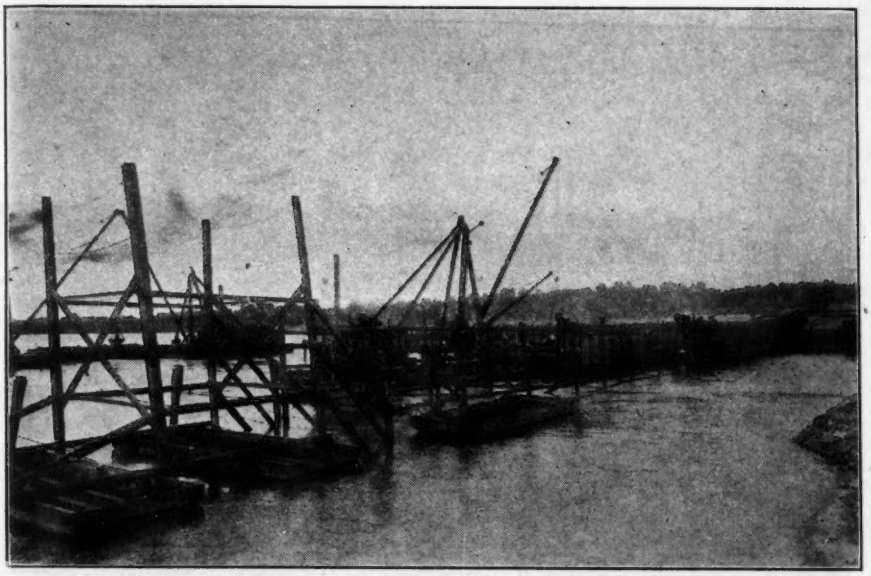
Typical Coffer-Dam.—A single form of coffer is generally used on the Ohio River. This "Ohio River Box Type" is illustrated in the photographs. It can thus be described in Mr. Lamphere's own words:

"It was built of 6 by 8-in., 20-ft. walers spaced about 4 ft. vertically. These were held by transverse rods spaced about 6 ft. In order to provide against an easy passageway for leakage, the least possible amount of timber bracing was placed between the sides of the coffer-dam. A continuous and vertically flexible framework is obtained by scarfing the ends of the walers and passing a rod through the scarfed joint. By placing the rods in vertical planes, a hinged joint was had at each panel joint.

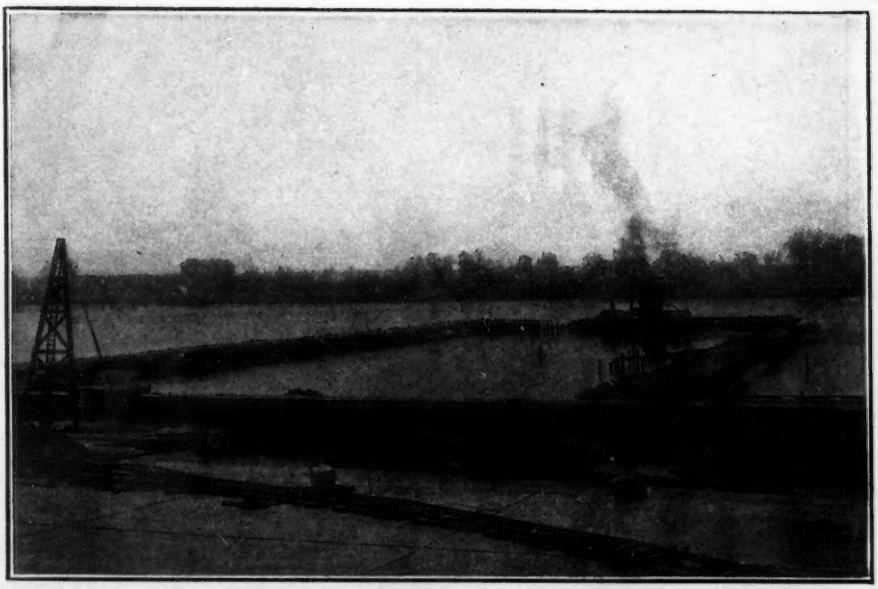
"This construction permitted the frame to be built in panels on a barge. Stiffness and proper width were secured by frames of 2-in. boards at each panel point. Completed panels as built on the barge were picked up by a derrick boat, the barge moved forward for the next panel, and the completed one lowered into the water. The hinge action permitted the rear end to go to the bottom, while the forward end rested on the rear end of the barge for connection to the next panel."

Depths greater than 14 ft. have to be filled in advance to this level. After sinking, the vertical 2-in sheeting is added and the whole is filled with fine river sand and then is protected on the top and around the corners by stone so that it will withstand the floods. In one instance, Mr. Lamphere noted that, "a coffer-dam with a total length of 2 500 ft. and enclosing 1 000 lin. ft. of the dam, was built complete and pumped out in 29 days." The photographs show various stages of work on such a dam.

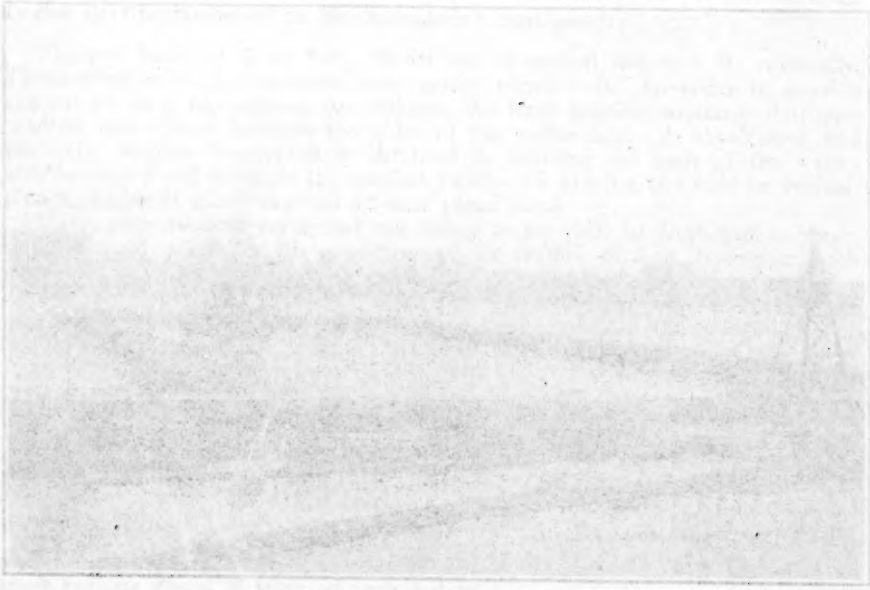
Still another type of dam has just been tried for the first time on the Ohio; it consists of a series of vertical cells about 40 ft. in diameter, each enclosed in steel sheet-piling.

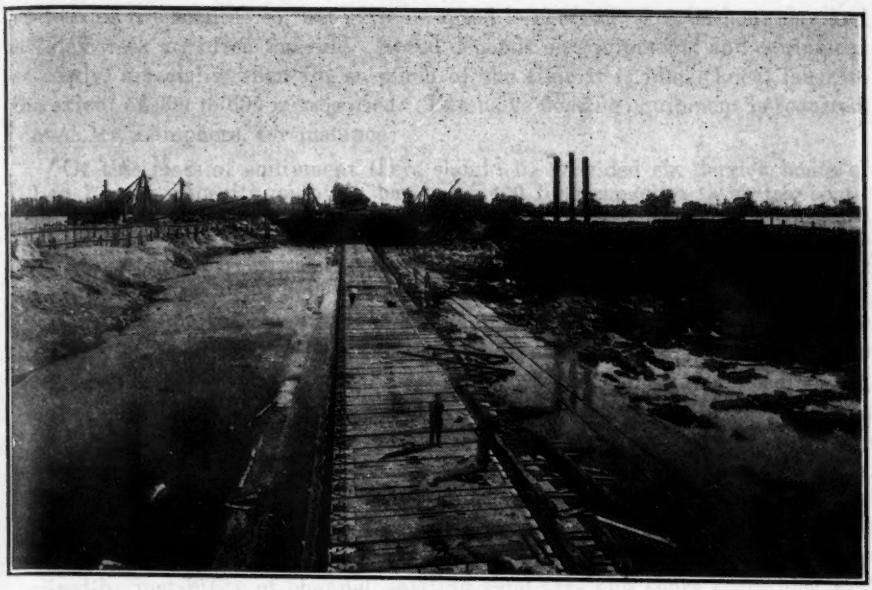


PROGRESSIVE STAGES IN COFFER-DAM BUILDING, OHIO RIVER.

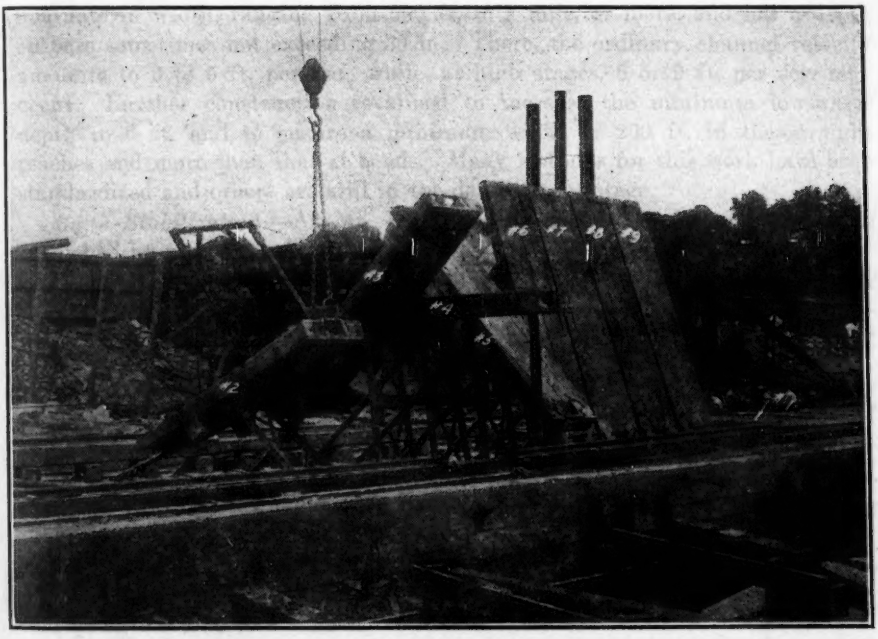


COFFER-DAM AFTER HIGH WATER, OHIO RIVER.

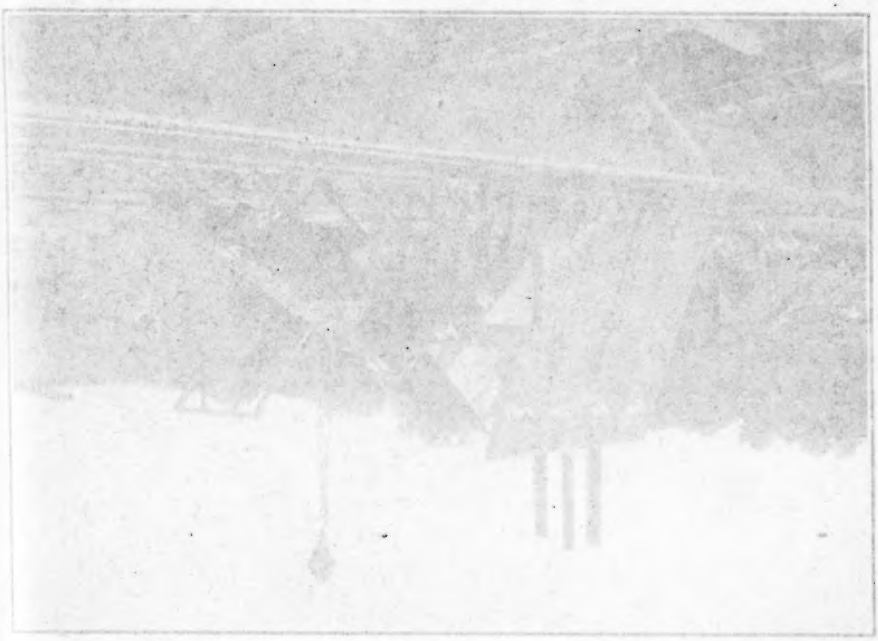


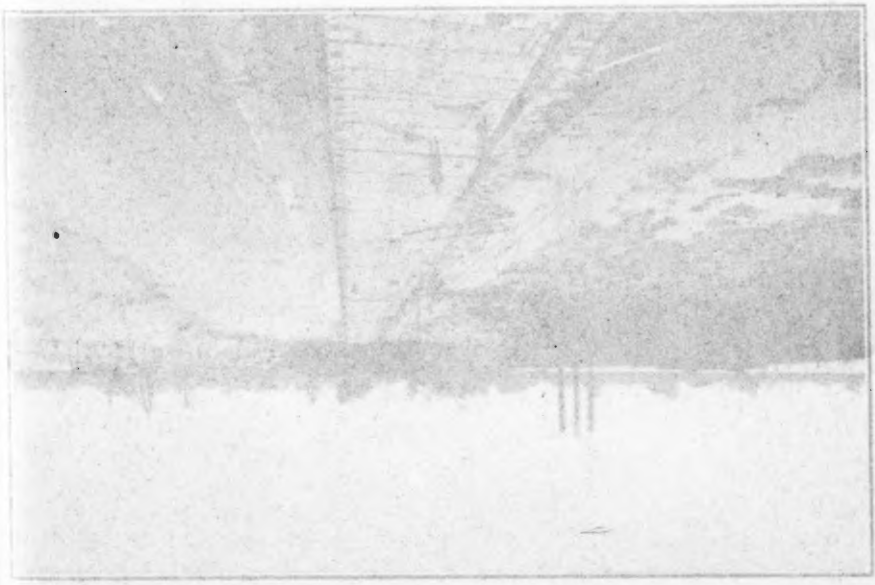


INTERIOR OF COFFER-DAM, OHIO RIVER, SHOWING STRUCTURE WITH WICKETS COMPLETED.



CLOSE VIEW OF WICKET DAM, SHOWING SEQUENCE IN RAISING OPERATION.





Progress of Work.—Sometimes the working season on the Ohio is as short as four or five months so that extreme speed is necessary. A 24-hour day and a 7-day week are often the rule. Speed depends on equipment; and equipment is costly, especially when for so much of the time it is idle. Local labor to the extent of 600 to 800 men is used. Extensive floating equipment is required, stated Mr. Lamphere, for instance:

"Of this class of equipment there should be provided six derrick boats of 10 to 15 tons capacity, eighteen barges of 400 tons capacity, three tow-boats, one 4-yd. dipper-dredge with two dump scows, three pile-drivers equipped with subaqueous hammers, two pump-boats with at least three 15-in. pumps each, together with various small work flats, gasoline launches, etc., all of which would cost about $500 000."

Speaking of the Chanoine wicket type of dam, Mr. Lamphere noted limitations in its operation. Since it is not designed for a great depth of flow over it, it has to be lowered quickly in the face of impending flood. This, in turn, quickly reduces the river level and is objectionable in particular in front of some cities. For this reason, and the reduced operating costs, there is a tendency to construct concrete fixed dams to replace these movable dams.

Problems of the Missouri River.—The improvements on the Missouri River are entirely different from those on the Ohio and are occasioned by essential differences in the type of stream. In its natural state, the Missouri "is characterized by instability of channel, shifting sand-bars and shore accretions, and extensive erosion of its alluvial banks by swift, undercutting currents."

Because of the deposit of this suspended material, the channel tends to fluctuate in width, ranging from 500 ft. to a mile, or more, and has a depth on bars sometimes not exceeding 30 in. There, the ordinary channel velocity amounts to 3 to 5 ft. per sec., while, at high stages, 8 or 9 ft. per sec. may occur. Further construction is aimed to increase the minimum low-water depth to 6 ft. and to ensure a minimum width of 200 ft. in the straight reaches and more than that at bends. Many methods for this work have been standardized and others are still in the development stage.

Bank Stabilization.—As Mr. Lamphere described, the protective work is furnished by a mattress,

"Placed below the usual low-water line. Above this water line the bank is first graded to a 3 on 1 slope and then paved with broken stone. The rock pavement is, of course, intended to prevent the destruction of the upper bank during high stages of the river."

The usual method of building this revetment has been by means of willows woven into a mat. More recently, however, the practice has developed of using lumber instead, due to the depletion of the willow supply. Similar methods are employed, 1-in. by 4-in. boards being used, placed 18 in. on center, and woven into a continuous mat on a barge which moves along as the weaving progresses.

As fast as the mat is made, it is floated, sunk, and weighted with stone to make it stay on the bottom. This avoids the risk of the mat floating away and being lost due to a sudden rise in the river.

Channel Alignment.—The pile dikes generally used for this work, Mr. Lamphere explained, resemble an enlarged picket fence,

"Constructed by driving two, three, or four rows of clumps of piling, which usually have 20 ft. of penetration in the river bottom, and extend to an elevation of 2 ft., or more, below the top of the adjacent river bank. The clumps consist of three piles each and are spaced about 15 to 25 ft. apart in each row and staggered with those in other rows."

Floating material becomes entangled in these dikes, eddies are formed, and sediment is deposited. Thus, a rapid accretion takes place and soon the dike itself becomes submerged. Sometimes, the bar forms during construction, then, "a contractor is in trouble when he organized for a floating equipment job and finds himself on a sand-bar."

Equipment.—The equipment necessary for an average dike or revetment job is given by Mr. Lamphere as follows:

"One large stern-wheel tow-boat for general towing and one smaller boat drawing not over 3 ft. for towing rafts of piles; two floating drivers with jets and steam hammers; one pump with a capacity of 200 gal. per min. with $\frac{7}{8}$-in. nozzle for grading bank, and with which three men can slope about 1 000 cu. yd. of bank in 8 hours; ten or twelve small auto trucks for handling stone from near-by quarries; ten barges and about six pontoons; one quarter boat to house and feed approximately 100 men and which should have an electric light plant; a water supply pump; and a water purifying plant."

The program for the Missouri River work, Mr. Lamphere notes, calls for concentration, for the time being, on the section below Kansas City, Mo. This, it is hoped, will be ready for traffic in about two years. The next section for improvement will be that between Kansas City and Sioux City, Iowa, which may require five years of intensive work and an expenditure of $60 000 000. These plans do not contemplate the need for locks or dams on the Missouri River.

OUTPUT FACTORS FOR MACHINE EXCAVATORS

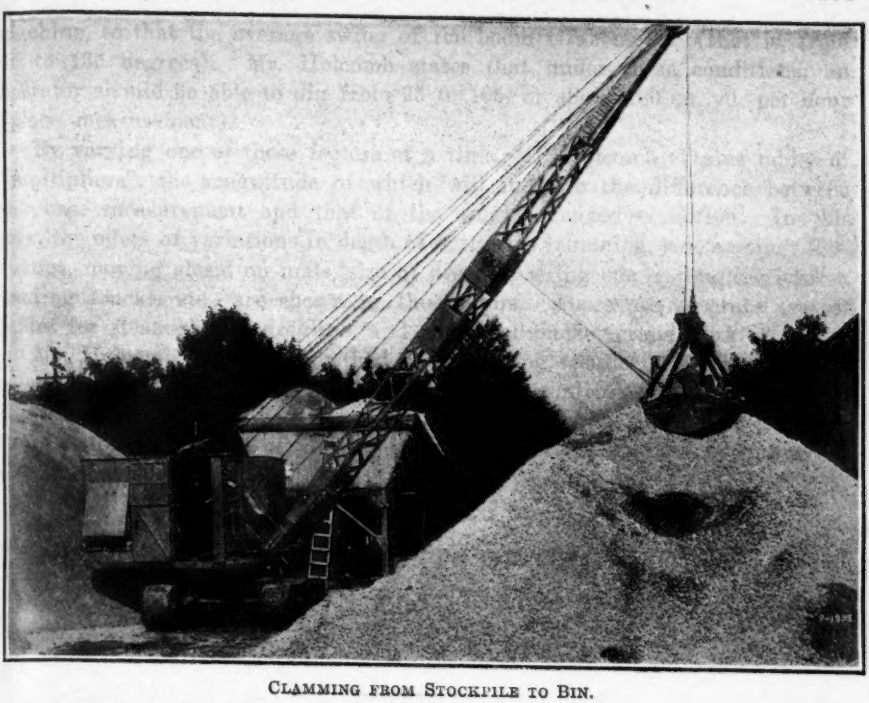
By A. E. Holcomb,* M. Am. Soc. C. E.

What will be the yardage output of the excavators operating under widely different conditions, such as those shown in the accompanying photographs? Mr. Holcolmb makes his attitude toward this question clear in the opening paragraph of his paper:

"There are so many variables entering into the possible yardage that may reasonably be expected under different conditions when excavating or rehandling materials, that it is impossible to set down any hard and fast rules for making prior estimates. There are, however, certain fundamental principles pertaining to operation that should be borne in mind and the writer, out of many years of experience and observation, has compiled a series of multipliers, based on average results obtained from known conditions of work and in different materials."

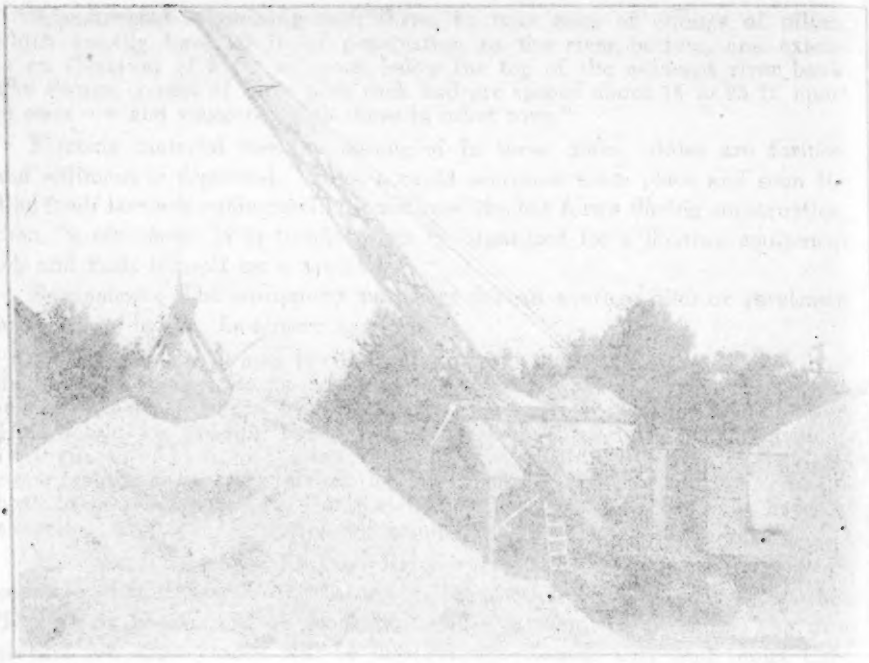
He outlines twelve fundamental principles that should be remembered by the estimator. As a base, he assumes an ideal condition of a 1-yd. dipper, excavating ordinary earth in an 8-ft. cut. Cars are loaded at the side of the

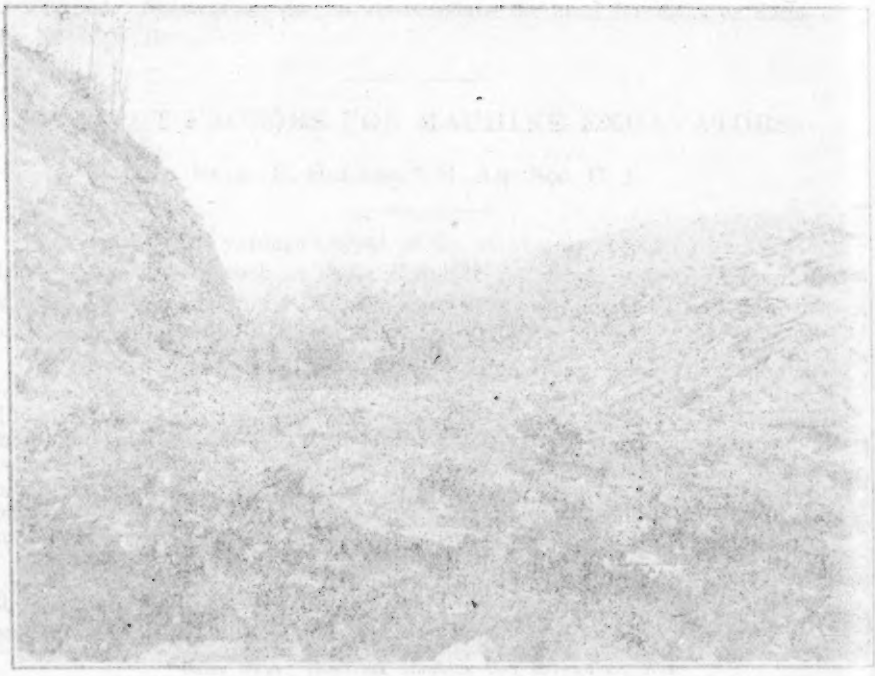
* Sales Engr., Koehring Machine Co., Milwaukee, Wis.



CLAMMING FROM STOCKPILE TO BIN.

BLASTING "SIDE CASTING" AND GRADING FOR ROAD.





machine, so that the average swing of the boom is about 90° (that is, from 45 to 135 degrees). Mr. Holcomb states that under these conditions, an operator should be able to dig from 95 to 105, or about 100 cu. yd. per hour (place measurement).

By varying one of these factors at a time, Mr. Holcomb obtains tables of "multipliers", the magnitude of which will indicate the difference between the base measurement and that of the single changed condition. In this way, the effect of variations in depth of cut, slope trimming, side casting, 180° swings, moving ahead on mats, size of dipper, casting empty dragline bucket, loading trucks, etc., are shown by the factors. There are separate sets of tables for steam-shovel, dragline, and chamshell-bucket crane work.

Mr. Holcomb explains a method of combining results by selecting multipliers from the different tables. The result is a composite factor with which the output of the excavator may be determined for the particular situation in question. The use of the tables is adequately explained by numerous examples.

LAKE FRONT IMPROVEMENTS OF CHICAGO, ILLINOIS: CONSTRUCTION PLANT AND METHODS

By J. E. Cahill,* M. Am. Soc. C. E.

This interesting paper was illustrated with slides and with four reels of motion pictures. Mr. Cahill began by outlining the history of lake front improvements since 1893, under the inspiration and active leadership of the late Mr. Daniel H. Burnham.

The City of Chicago is bounded on the east by Lake Michigan for a distance of about 25 miles. Justification for reclaiming the lake front is contained in a statement that:

"Most of the business and densely populated sections of the city are located within a short distance of this eastern boundary, or Lake Front. The most logical and economical method of increasing the park and boulevard areas nearest the heavily congested sections of population and traffic was by the reclamation of submerged lands and the extension lakeward of such park and boulevard areas. Such new land was reclaimed or made at less than one-tenth the valuation of adjacent lands."

By filling in land along the shore to depths as great as 22 ft., the Park Board Commissioners have been instrumental during the past fifteen years in constructing drives and parks that will ultimately serve to connect the South Park and the Lincoln Park Boulevard Systems. The total project calls for the reclamation of about 10 000 acres of land with a total estimated value of $5 000 000 000. Concerning progress, Mr. Cahill states:

"Nearly all the more important construction work has been completed and many years have been spent with special equipment and methods to carry on this work rapidly to completion.

* Asst. Div. Mgr. and Constr. Engr., Great Lakes Dredge & Dock Co., Chicago, Ill.

"In general, the procedure on this Lake Front Improvement work was as follows:

"*First.*—Construct bulkheads or breakwaters in 15 to 25 ft. depth of water.
"*Second.*—Place pressure bank filling immediately back of bulkhead.
"*Third.*—Place general filling.
"*Fourth.*—Place black dirt for soil on top of general fill.
"*Fifth.*—Construct roadways, drainage, structures, landscaping, etc."

Breakwaters.—For bulkheads or breakwaters, two parallel rows of piling, generally 20 ft. apart, were filled with stone. Mr. Cahill gives details thus:

"Each row of piling was driven in a tight close line and these two rows of piling were tied together with two sets of anchor rods, top and bottom, and the space between the two rows was filled with stone. This filling stone was of various sizes to give greatest weight per cubic foot of volume and was capped with 2 to 5-ton stone to keep the lighter stone from washing out. The tops of the timber piling were cut off at about 5 ft. above datum and riprap stone was deposited against the lakeward side of the bulkhead from the lake bottom up to about 10 ft. below datum to protect the bulkhead against heavy storms.

"The pressure bank filling of good clay was deposited directly behind the landward side of the bulkhead in the form of an embankment. This had a top width of about 50 ft. and a top elevation of about 5 ft. above datum with the clay having a long natural slope landward. The Park Board Engineers have found from experience the superiority of good virgin clay as a filling material for the construction of these pressure banks. Where clay was used for pressure banks the practice was to omit vertical wooden sheeting from the land side of the bulkhead for economy."

The alignment was in long sweeping curves, imitating natural shore lines.

Construction Plant.—The protection of plant and equipment on this work was a serious problem because:

"All this land reclamation work must be done from the open lake and hence is exposed to waves and storms from at least the north, east, and south directions and often from the land or west and from swells, all of which caused delays or stoppage of operations. The yacht harbors in the parks are not of sufficient depth and there are no harbors of refuge near at hand except the distant main harbor at Chicago. Therefore, all construction equipment had not only to perform the required work efficiently and economically, but also had to withstand possible damage or loss due to storms.

"In general, the specifications for the Lake Front Improvement Work at Chicago carried a provision limiting the working period of construction each year to the 'Season of Navigation' or April 15 to November 15. This working period was therefore only seven months, or 58% of the calendar year, and out of these seven months we suffered many large, long, and costly delays due to bad weather conditions in these exposed locations. With a time efficiency of 50% we really worked only about three and one-half months per year in the exposed lake. This work, therefore, required the best designed, constructed, and operated equipment to accomplish the maximum amount of work in the minimum of time. The construction of this new and highly efficient plant brought with it a new problem, which was the selection, development, and education of men to operate and maintain this plant so as to obtain the required and greatest degree of performance and efficiency."

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EXPERIMENTAL RESEARCH ON VIBRATION DAMPERS AND INSULATORS

By Stephen E. Slocum,* M. Am. Soc. C. E.

Synopsis

The study of vibration insulation presented in what follows is an original research undertaken in connection with the general problem of preventing vibration in structures, as applied in particular to the terminal improvements of the Pennsylvania Railroad at Philadelphia, Pa., now (1928) under construction.

In order to study the transmission of vibration it was necessary to have two vibrating systems to act as transmitter and receiver, respectively. Each of these elastic systems had its own vibration characteristics. Moreover, the insulator placed between them was also elastic and resilient and, therefore, added a third vibrating element. Loads were also transmitted through this threefold composite system, which had a further effect in modifying the vibration characteristics.

It is a notable fact, however, that no practical solution has yet been found of the vibration characteristics of such a primary element as a simple beam of uniform cross-section under load. Simplifying assumptions, such as neglecting the mass of the beam, or assuming that it is unloaded, have always been found necessary to a mathematical solution, and these make the results of such analysis of little practical value.

Moreover, such experimental studies of vibration insulators as have appeared, have also been of a very special nature and so limited in scope as to warrant no general conclusions. It is evident, therefore, that the present study is of a somewhat pioneer nature in a difficult field of growing practical importance. It is believed that the essential features of the problem have been kept distinct, and that practical results have been brought to light concerning the general problem of vibration control.

Note.—Written discussion on this paper will be closed in February, 1930, *Proceedings*.

* Cons. Engr., Ardmore, Pa.

Vibration Control

The use of insulation for creating a short circuit in vibration in structures is only one phase of the complicated problem of vibration control. The general problem, whether considered in relation to structures or machinery, is a dynamic rather than a static one. Probably it is for this reason that greater progress toward a solution has been made in mechanical than in structural lines.

The general problem of vibration control may be classified under several heads. In the design of permanent machinery installations, such as lighting and power units in office buildings and apartments; batteries of looms, printing presses, or machine tools in shops and factories; marine installations; automotive and aircraft power plants, etc., the first step toward a solution consists in eliminating the unbalanced effects in rotating parts by means of dynamic balancing.

This alone, however, is in general only partly effective. In reciprocating machinery where the power fluctuates, it is of the utmost consequence so to design parts affected by vibration as to avoid critical speeds. In relation to building construction, critical speeds are those at which synchronous vibrations are set up in one or more members of the structure. When vibration is due to permanent machinery installations, such synchronous vibrations may be avoided, as in machinery, by properly designing individual structural members, such as columns and girders.

The third general principle, applying particularly to structural work, consists in causing the vibration to become "short-circuited" by confining it to the region where it originates. For example, a machine may be mounted on a structure entirely independent of those adjacent to it; various types of insulation may be interposed between the structures; nodes may be artificially created at points of contact; or use may be made of existing nodes in the structure, the latter in particular being a very useful method in marine installations.

Mechanical insulators fall into two general classes: Those that are elastic and resilient, such as cork, felt, and rubber; and those that are almost or entirely lacking in these qualities, such as asbestos, lead, sand, and gravel. Properly speaking, there is no such thing as a vibration absorbent, since this implies dissipation of energy through internal work in the form of molecular friction, heat losses, etc. Resilient materials store up energy like a spring, and give out this energy again when released without appreciable loss; and the damping properties of non-resilient materials, such as sand and gravel, depend on destroying the rigidity, or interrupting the continuity, of otherwise rigid structures.

Description of Apparatus

For the purpose of this study it was essential to have two elastic systems, one of which could be set in vibration mechanically and would serve as transmitter, while the other could be insulated from the first by the material under test, and would serve as receiver of such vibration as passed through the insulation. It was also considered essential to provide for a considerable range of

loads on the test piece, and for varying the frequency of the forced vibration within practical limits. The general arrangement of the test apparatus designed to meet these requirements is shown in Fig. 1.

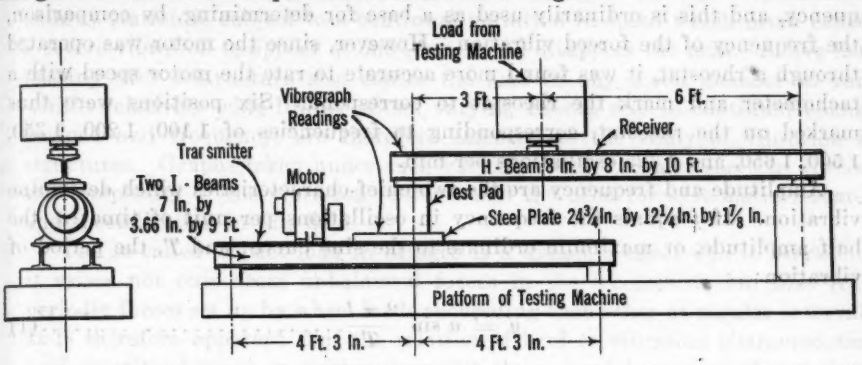

Load from Testing Machine
Vibrograph Readings
3 Ft.
6 Ft.
Receiver
Trar smitter
H - Beam 8 In. by 8 In. by 10 Ft.
Two I - Beams 7 In. by 3.66 In. by 9 Ft.
Motor
Test Pad
Steel Plate 24¾ In. by 12¼ In. by 1⅞ In.
Platform of Testing Machine
4 Ft. 3 In.
4 Ft. 3 In.

FIG. 1.—ARRANGEMENT OF TESTING APPARATUS.

To secure the desired loading, and also a long platform on which to set up the test apparatus, a large testing machine, with a platform 20 ft. long, was chosen as a base for the experiments. The primary vibrating system, or transmitter, consisted of two 7-in., 15.3-lb., I-beams, 9 ft. long, mounted parallel to each other, and lengthwise of the platform of the testing machine. On this pair of I-beams, a 1-h.p. electric motor, with an unbalanced driving pulley, was clamped, to produce the forced vibration. At the center of the beams and adjacent to the motor a machined steel plate was clamped lengthwise to form a platform for the insulating material under test (Fig. 1). On this platform, beside the test pad, was placed the "vibrograph" by which the amplitude of the forced vibration was recorded.

The unbalanced effect on the driving pulley of the motor was obtained by removing one of the bolts by which the pulley was attached to the flange and replacing it with a longer one carrying a heavy nut at each end. The motor speed, or frequency of the forced vibration, was controlled by a rheostat giving a speed range from 1 100 to 1 725 rev. per min.

Directly over the transmitter, an 8-in. 31-lb., steel H-beam, 10 ft. long, was mounted so that one end was supported on the insulating material under test, and the other end blocked up on the platform of the testing machine. This H-beam constituted the secondary vibrating system, or receiver.

The load from the testing machine was applied to this H-beam through a spherical bearing-block. By this means both the static load and the dynamic vibration were in all cases transmitted through the insulating material under test.

VIBROGRAPH RECORDS

The graph traced by the vibrograph was a simple sine or cosine curve, without harmonics, which represents the simplest possible type of vibration. Throughout the entire series of tests the ratio of amplification was 12; that is, the amplitude of the graph traced by the instrument was twelve times the

amplitude of the actual vibration. As reproduced in this paper, the vibrographs are six times the actual scale of amplitude, or one-half the full size as traced.

The instrument has an auxiliary pen that traces a graph of known frequency, and this is ordinarily used as a base for determining, by comparison, the frequency of the forced vibration. However, since the motor was operated through a rheostat, it was found more accurate to rate the motor speed with a tachometer and mark the rheostat to correspond. Six positions were thus marked on the rheostat, corresponding to frequencies of 1 100, 1 200, 1 350, 1 500, 1 650, and 1 725 oscillations per min.

Amplitude and frequency are the two chief characteristics which determine vibration. If f equals the frequency in oscillations per unit of time; a, the half amplitude, or maximum ordinate to the sine curve; and T, the period of vibration:

$$y = a \sin \frac{2 \pi t}{T} \qquad (1)$$

The maximum acceleration, α, is given by the formula:

$$\alpha = 4 \pi^2 f^2 a \qquad (2)$$

Since acceleration is the fundamental quantity of dynamics, the vibrograph records evidently determine fully the characteristics of the vibration.

The readings were taken by placing the instrument alternately on the test platform of the transmitter beside the test pad, and on the upper flange of the H-beam, or receiver, directly over its point of support on the test pad. In each position a graph was recorded at each of the six speeds to which the rheostat was calibrated. Each test at a given load, therefore, comprised two sets of six vibrograph records, or twelve graphs altogether.

Moreover, the tests covered a considerable range of loads. For materials like sand, gravel, lead, and asbestos, the test loads as measured on the scale-beam of the testing machine ranged from 300 to 24 000 lb., corresponding to a maximum unit intensity of loading on the test pad of 450 lb. per sq. in. In some cases this schedule required a total of ninety-six vibrograph records for one complete test. For corkboard and similar materials on which the load range was more limited, a complete test usually totaled forty-eight records.

The speed of the drum carrying the paper roll on which the graph was traced, was regulated by a governor which maintained the angular velocity constant. The linear speed of the paper passing under the pen, therefore, depended on the diameter of the roll. The graph thus appears more extended in some cases than in others, depending on the diameter of the paper roll when the record was taken. This does not affect the frequency, since the frequency was determined by calibrating the rheostat.

Interpretation of Graphs

The test apparatus was assembled from commercial units, subject to the usual variations in uniformity of shape and loading actually met in practice. The results are, therefore, more typical of actual conditions in engineering than would have been the case with apparatus of greater refinement, such as might be available in a physics laboratory.

If a single load or a single frequency had been adopted, doubtless the results would have shown a greater uniformity, but it is precisely this lack of uniformity that is met in practice. A train entering or leaving a terminal or subway station is subject to a continual variation in speed which often causes a severe vibration to appear at one instant and disappear the next. A live load passing over a structure also causes the load in any given member to vary within relatively wide limits. Such varying effects, due to continual change in load and frequency, are therefore essential to the study of vibration in structures. Graphs taken under such varying conditions also serve to disclose the complexity of the vibration problem and the need for systematic research and specialization in this field.

The so-called impact load in bridges is a dynamic effect due to vibration; it arises not only from unbalanced forces in the locomotive, but also from periodic forces set up by wheel loads succeeding each other at regular intervals. It is therefore apparent that the relation of load to vibration characteristics, such as critical speed or synchronism with the natural frequency of structures, is of great importance in many branches of engineering.

About 2 000 records were taken in the course of these tests. Those chosen for illustration in this paper are typical, and display certain characteristic properties of the material or loading.

It is evident on inspection that load has a marked effect in modifying vibration characteristics. Thus, Fig. 2(*a*) and Fig. 2(*b*), taken with the same unit load, exhibit similar characteristics; whereas Fig. 3(*a*) and Fig. 3(*b*), taken with the same insulating pads, but with a different unit load, show quite different characteristics. In Fig. 3, the motor speed is synchronized with the natural frequency of the transmitter.

Frequency has little effect on the damping properties of insulation—that is, on the percentage of amplitude damped out by the pad—except at critical points. The percentage of damping, however, depends very largely on the kind of insulation, or the material of which the pad is made, as will appear more fully later.

In interpreting the vibrographs, therefore, the effect of load, material, and frequency must all be clearly distinguished in making comparisons.

Corkboard Insulation

The insulating properties of any type of resilient pad is a function of its deflection under load. Experience has shown that in order to secure the best results in machinery insulation it is important to adjust the dimensions of the pad to the load and, also, to the speed of the machine, or frequency of vibration. Either the thickness of the pad may be changed, keeping the area constant; or the area may be altered, keeping the thickness constant. In either case, the deflection of the pad under load is affected, which is the chief quality on which its properties as a vibration damper depends.

Corkboard is widely used for vibration insulation, and is commercially standardized for this purpose as to density and dimensions. For test purposes blocks of corkboard were used, 6 by 6 in. in area by 3 in. thick. They were of standard density equal to 0.319, which is equivalent to a unit weight of 1.66 lb.

per board-ft. The compressibility of this material under load is given by the load-deflection curve shown in Fig. 4, plotted from test data obtained from one of these pads.

The corkboard blocks were piled up so as to give four thicknesses for vibration tests, namely, 3 in., 6 in., 9 in., and 12 in. Each pad was tested for a series of loads, and vibrographs were taken at six frequencies for each load. The results obtained with two of these thicknesses of corkboard pad under a unit load of 27 lb. per sq. in., are shown in Fig. 2.

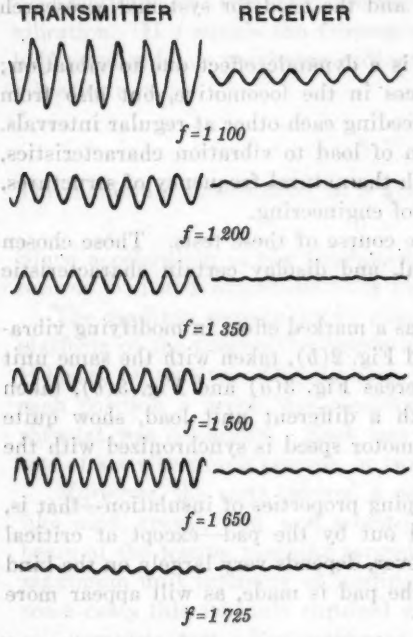


FIG. 2(a).—VIBROGRAPH OF CORKBOARD, 6 BY 6 BY 6 IN. (UNIT LOAD, 27 LB. PER SQ. IN.)

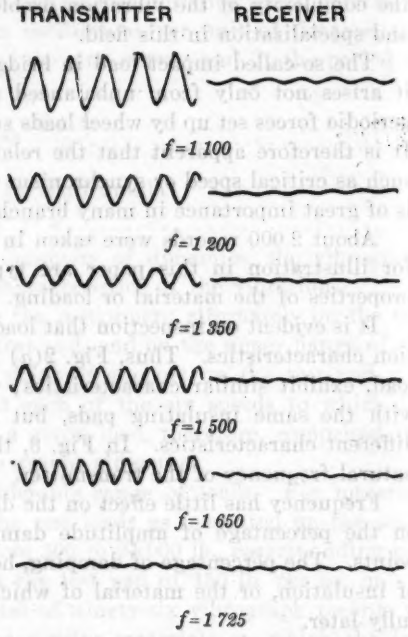


FIG. 2(b).—VIBROGRAPH OF CORKBOARD, 6 BY 6 BY 12 IN. (UNIT LOAD, 27 LB. PER SQ. IN.)

If T denotes the amplitude of vibration of the transmitter, and R, the amplitude of vibration of the receiver, then $k = \frac{R}{T}$ may be assumed to indicate the amount of damping. With this notation, the percentage of amplitude of vibration damped out by the pad becomes $D = 100(1 - k)$. By scaling the amplitudes from the vibrographs and determining the damping percentage it is found that, for the first five frequencies, the damping percentage for a given depth of pad is practically constant. The average values of D for these five frequencies are plotted in Fig. 5.

It is further evident from Fig. 2 that, at the highest frequency, namely, 1 725 oscillations per min., the amplitude of vibration of the transmitter decreases greatly and suddenly, while that of the receiver is not materially affected. This does not mean that the damping effect is lost, but that this

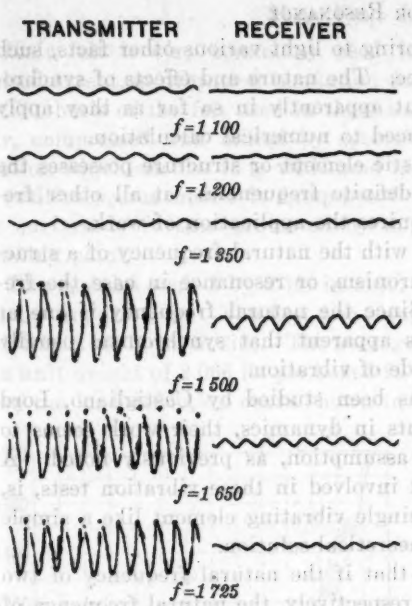


FIG. 3(*a*).—VIBROGRAPH OF CORKBOARD, 6 BY 6 BY 6 IN.

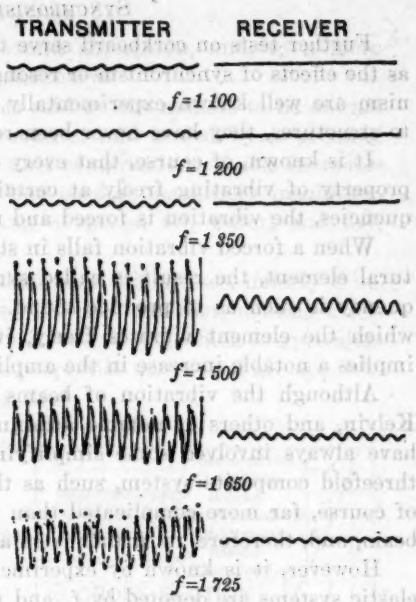


FIG. 3(*b*).—VIBROGRAPH OF CORKBOARD, 6 BY 6 BY 12 IN.

particular frequency corresponds to a critical point, or node, of the transmitter. This further indicates the value of carrying such vibration experiments over a considerable range of loads and frequencies, because the results obtained at a critical point have a special rather than a general significance.

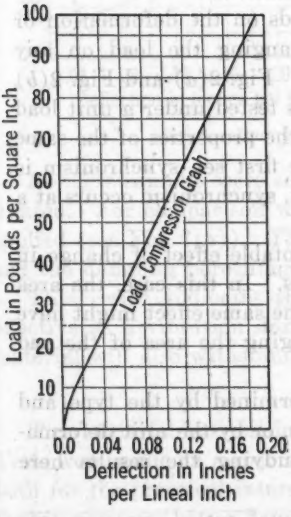


FIG. 4.—COMPRESSIBILITY OF CORKBOARD.

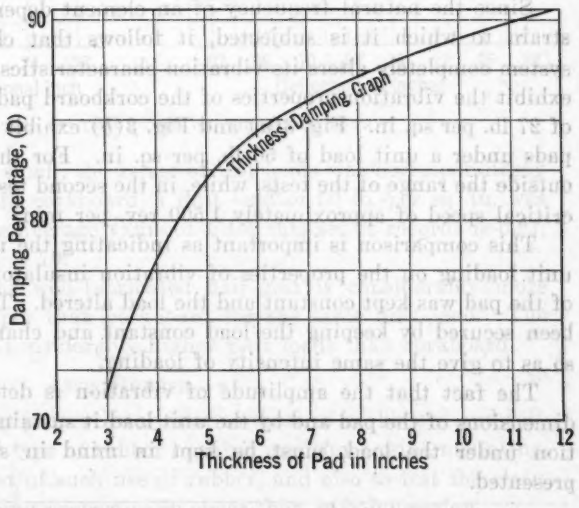


FIG. 5.—EFFECT OF THICKNESS ON DAMPING

Synchronism or Resonance

Further tests on corkboard serve to bring to light various other facts, such as the effects of synchronism or resonance. The nature and effects of synchronism are well known experimentally, but apparently in so far as they apply to structures, they have never been reduced to numerical calculation.

It is known, of course, that every elastic element or structure possesses the property of vibrating freely at certain definite frequencies; at all other frequencies, the vibration is forced and requires the application of work.

When a forced vibration falls in step with the natural frequency of a structural element, the result is called synchronism, or resonance in case the frequency is such as to produce sound. Since the natural frequency is one at which the element vibrates freely, it is apparent that synchronism usually implies a notable increase in the amplitude of vibration.

Although the vibration of beams has been studied by Castigliano, Lord Kelvin, and others of notable attainments in dynamics, their work seems to have always involved some simplifying assumption, as previously noted. A threefold composite system, such as that involved in these vibration tests, is, of course, far more complicated than a single vibrating element like a simple beam, and, therefore, is further from a theoretical solution.

However, it is known by experiment that if the natural frequency of two elastic systems are denoted by f_1 and f_2, respectively, the natural frequency of the composite system, in general, will be neither f_1 nor f_2. An insulating pad, such as those tested, also has a marked effect on the natural frequency of the composite system. This effect of insulation was studied by Berger,* who found that the nature of the material, as well as the area and thickness of the pad, affected the amplitude of vibration and the natural frequency, or point of synchronism. He found, for example, that at a given frequency, an insulating pad of improper dimensions might serve to intensify the amplitude of vibration.

Since the natural frequency of an element depends on the deformation or strain to which it is subjected, it follows that changing the load on any system completely alters its vibration characteristics. Fig. 2(*a*) and Fig. 2(*b*) exhibit the vibration properties of the corkboard pads tested under a unit load of 27 lb. per sq. in. Fig. 3(*a*) and Fig. 3(*b*) exhibit the properties of the same pads under a unit load of 50 lb. per sq. in. For the first set, synchronism is outside the range of the tests, while, in the second test, synchronism occurs at a critical speed of approximately 1 500 rev. per min.

This comparison is important as indicating the notable effect of change in unit loading on the properties of vibration insulators. In this case, the area of the pad was kept constant and the load altered. The same effect might have been secured by keeping the load constant and changing the area of the pad so as to give the same intensity of loading.

The fact that the amplitude of vibration is determined by the type and dimensions of the pad and by the unit load it sustains, or by the unit deformation under the load, must be kept in mind in studying the results here presented.

* *Gesundheits Ingenieur*, 1913, Vol. 36, p. 433.

Hair Felt Insulation

Hair felt is very commonly used for sound absorption, and, to a more limited extent, as vibration insulation for machinery.

The basis of the felt used in these tests is said by the makers to be animal hair, compressed and milled by special processes, and sealed by a proofing solution which enables it to withstand high unit compression; it also increases its resiliency, and makes it damp-proof. When used as machinery insulation, the surface is further protected by applying a special oil, water, and fire-resisting paint.

The samples were 3 by 2 in. in area, and in four thicknesses, namely 1 in., ½ in., ¼ in., and ⅛ in. The first two samples were used together, making a test pad, 3 by 2 by 1½ in. in size. The average density was 0.397, which is equivalent to a unit weight of 2.066 lb. per board-ft. Its properties under load are apparent from the load-deflection curve shown in Fig. 6(*a*).

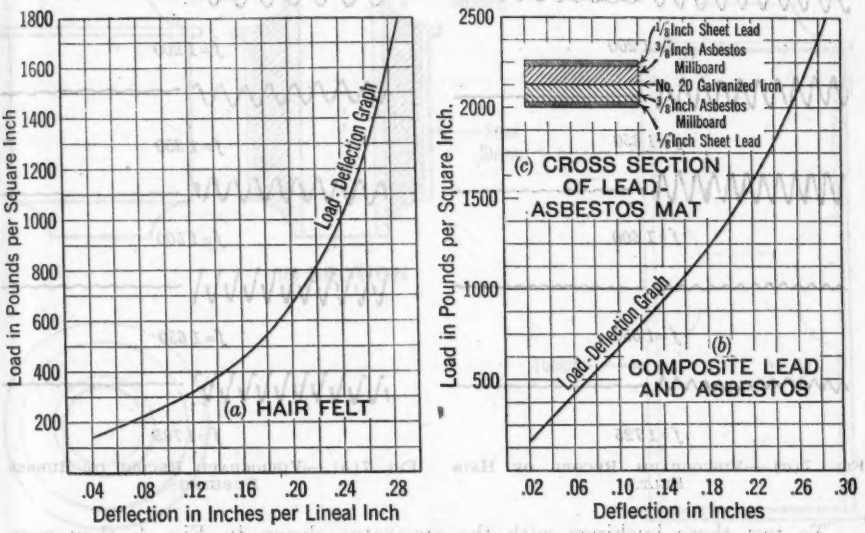


Fig. 6.—Properties of Two Types of Vibration Mats.

As these samples were so small, the range of test loads was correspondingly limited. For comparison with corkboard, a unit load of 50 lb. per sq. in. was applied (see Fig. 7(*a*)). The average value of k for this set of records is 0.21, and the damping percentage is 79.

This result indicates that well-fabricated hair felt is considerably more effective as a vibration damper than corkboard for the same unit load. The material will also withstand considerably higher unit loads than corkboard.

Live Rubber

This material has resilient properties similar to those of corkboard and felt. Tests were made on a special type of rubber bushing used for engine mounting, both for the practical interest of such use of rubber, and also to test the claim that it possesses better damping properties in shear than in compression.

As shown in Fig. 8(*b*), these mountings comprised inner and outer metal sleeves, united by a moulded rubber bushing, through which the load was transmitted in shear from one steel sleeve to the other. These bushings are intended to be mounted axially, putting the rubber in shear and loading it symmetrically and uniformly. Evidently, they would be much less effective as vibration dampers if mounted radially, since only a small part of the rubber would be in action, and even on this segment the load would not be distributed uniformly.

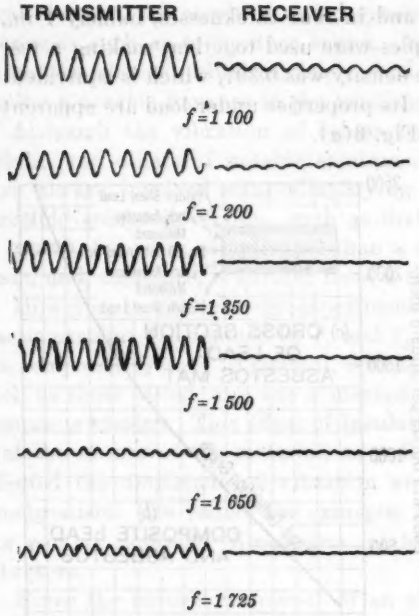


FIG. 7(*a*).—VIBROGRAPH RECORD OF HAIR FELT.

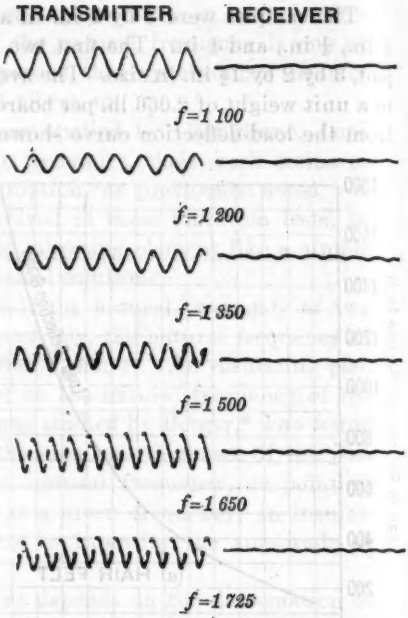


FIG. 7(*b*).—VIBROGRAPH RECORD OF RUBBER BUSHINGS.

To test these bushings with the apparatus shown in Fig. 1, they were mounted in pairs in a short section of pipe, as shown in Fig. 8(*c*). Two such pairs, or four bushings, were then used as legs for supporting the end of the H-beam on the test platform. With this arrangement, each pair carried one-half the reaction at the end of the H-beam, and this load passed through two bushings. Each one thus carried exactly the same load, but as the vibration passed through two bushings in series, the amplitude of vibration was damped twice as much as for a single bushing.

The manufacturer's rated loading for this type of bushing is 150 to 200 lb. per bushing. They were tested as vibration dampers in the manner just explained under three different loads, the vibrograph records in Fig. 7(*b*) being for a load of 224 lb. per bushing.

The average damping factor determined from this test was 0.096 per pair in series. For a single bushing, therefore, the value would be approximately

twice this amount, or $k = 0.19$. Consequently, the percentage of damping for bushings of this particular type and loading is found to be 81. For a load of 160 lb. per bushing, the damping percentage was found to be 85.

Asphalt Emulsion

One of the most important forms of vibration insulation in structural work is lateral insulation around piers and column footings. For this purpose a light grade of corkboard is often used because the insulation is introduced simply as a separator and transmits no load. Plastic or semi-fluid materials might also be used as lateral insulation, simply poured into cracks. With this in mind, an asphalt emulsion was tested to determine its properties as a vibration damper. This was received in a semi-fluid condition.

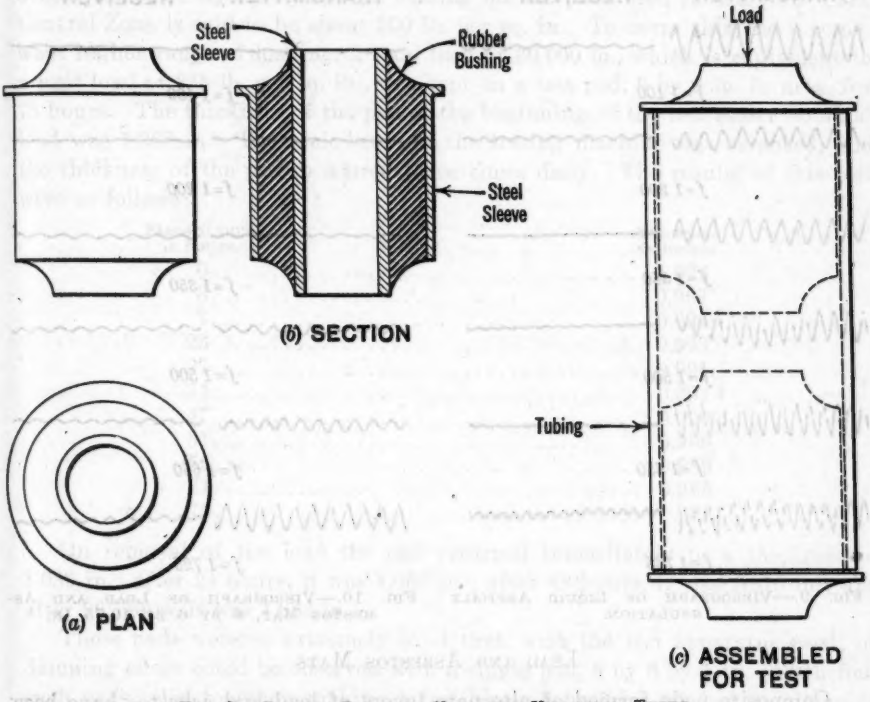


Fig. 8.—Rubber Bushing Used for Vibration Tests.

To test the material in this state, it was necessary to confine it in a rectangular tin can, 9 by 6½ by 4 in. This container was filled with the asphalt emulsion until it bulged and was then placed on the test platform with its 4-in. dimension vertical. A square steel plate, 6 by 6 by 1½ in., was placed on the can, and this, in turn, supported the end of the H-beam, or receiver. In shape and dimensions, this test pad was, therefore, very similar to the corkboard pads tested. In the case of lateral insulation, the load is nominal. A light load of 396 lb. (11 lb. per sq. in.) was therefore applied to the steel plate. The vibrograph records for this test are shown in Fig. 9. These give an average value of $k = 0.113$, or a damping percentage of 88.7.

This material dries out in air, however, and although it does not completely harden, but remains plastic or sticky, it possesses little or no resilience. Therefore, although it would not transmit vibration like a rigid body under any conditions, its effectiveness as a vibration damper would be relatively small.

However, this test was otherwise useful as confirming the results obtained with resilient materials, such as corkboard, felt, and rubber, since the can with its semi-fluid contents was highly resilient, offering very slight resistance to deformation and resuming its shape instantly on removal of load. The results of this test, therefore, confirm fully the general conclusion that the qualities essential to an effective vibration insulator are slight resistance to deformation and complete resilience.

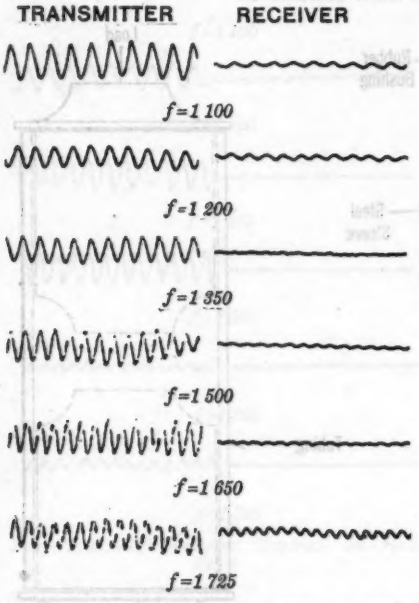


FIG. 9.—VIBROGRAPH OF LIQUID ASPHALT INSULATION.

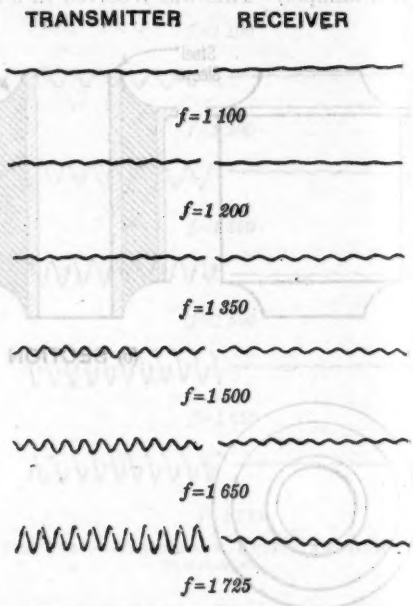


FIG. 10.—VIBROGRAPH OF LEAD AND ASBESTOS MAT, 6 BY 6 BY 10.75 IN.

LEAD AND ASBESTOS MATS

Composite pads formed of alternate layers of lead and asbestos have been used extensively by the New York Central Railroad Company in the Terminal Zone, New York, N. Y., as vibration mats under column footings. A large number of tests, therefore, were made on such pads to determine their properties as vibration dampers, as well as their physical properties with respect to resilience and deflection or lateral deformation under load. The pads tested were identical in make-up with the vibration mats used in the construction of the Graybar Building,* New York, which were originally devised as sound deadeners. They have proved effective in eliminating low pitched noises of approximately 50 oscillations per sec.

* *Engineering News-Record*, February 10, 1927, pp. 228-230.

The standardized mat adopted in this work consists of five separate layers, as shown in Fig. 6(*c*). The bottom layer of sheet lead is turned up and folded over the top layer as a protection against water. Care was taken, in making up the test pads, to use the same quality of asbestos millboard, from the same manufacturers, as specified for the vibration mats used in the Graybar Building. The total thickness of such a composite pad is approximately $1\frac{7}{16}$ in.

To determine this deformation under heavy loads, a sample pad, 6 by 6 in. in area, was tested in compression up to a total load of 100 000 lb., which is equivalent to a unit load of 2 778 lb. per sq. in. The load-deflection curve obtained from this test is shown in Fig. 6(*b*). No lateral spreading of either lead or asbestos layers could be detected at any load.

A second test was made on a similar pad to observe the effect of time on deflection. The unit intensity of loading on the pads used in the New York Central Zone is said to be about 500 lb. per sq. in. To cover this and a somewhat higher range of loading, a total load of 30 000 lb., which is equivalent to a unit load of 833 lb. per sq. in., was kept on a test pad, 6 by 6 in. in area, for 75 hours. The thickness of the pad at the beginning of the test under nominal load was 1.088 in. The scale-beam of the testing machine was balanced, and the thickness of the pad measured three times daily. The results of this test were as follows:

Elapsed time, in hours.	Thickness, in inches.
0	1.022
3	0.997
7	0.994
23	0.993
27	0.991
31	0.991
47	0.990
51	0.989
55	0.989
71	0.988
75	0.988

On removal of the load the pad returned immediately to a thickness of 1.039 in.; after 24 hours, it was 1.060 in.; after 48 hours, it was 1.076 in.; and after 96 hours, it was 1.086 in.

These pads were so extremely solid that, with the test apparatus used, no damping effect could be observed with a single pad, 6 by 6 by 1 in. With four such pads piled together, making a test block, 6 by 6 by $4\frac{7}{16}$ in., the damping effect was still so slight that its numerical value could not be definitely determined.

To amplify the damping effect sufficiently to get more pronounced and reliable results, ten such pads were piled together. In two of these pads the thickness of the asbestos layers was $\frac{1}{4}$ in. instead of $\frac{3}{8}$ in.; in all other respects, the pads were exactly identical. This composite tenfold test pad, comprising altogether 40 layers of sheet lead, 40 layers of asbestos millboard, and 20 sheets of galvanized iron, made up a block, 6 by 6 in. in area by $10\frac{3}{4}$ in. deep. It was tested for the full series of loads, ranging from 1 500 to 24 000 lb. on the scale-beam of the testing machine, which was equivalent to unit loads on the pads ranging from 35 to 450 lb. per sq. in.

Typical results from this series of tests are shown in Fig. 10. For a unit load of 450 lb. per sq. in., the average value of the damping ratio is $k = 0.48$, and, consequently, the percentage of damping for ten pads is 52. When the unit load was 340 lb. per sq. in., k was 0.45 and D was 55%; and with a unit load of 62 lb. per sq. in., the results were the same.

The average for the entire test series, comprising 228 vibrograph readings, and unit loads ranging from 35 to 450 lb. per sq. in., k, was found equal to 0.51, and, consequently, the total average damping percentage for ten pads was 49. The results indicate that as the unit load on the pad increases, the damping effect diminishes, which is confirmed by the results obtained with other materials comprised in this series of tests.

For a single pad of this type, of nominal thickness of 1 in., carrying a unit working load of 450 to 500 lb. per sq. in., and for the low frequencies covered by the tests (1 100 to 1 725 oscillations per min.), the percentage of amplitude of vibration damped out may be fixed at about 5.

Effect of Constraint

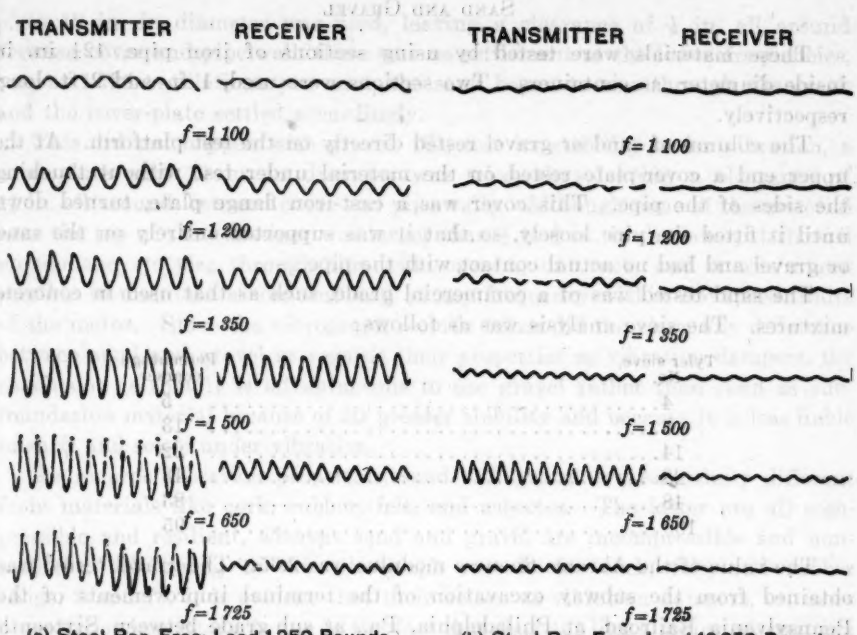
A series of vibrograph records was taken with the test pad replaced by a machined steel bar, 15 by 3¼ by 1½ in. in size, placed on edge and crosswise, on the test platform; that is, with the 3¼-in. dimension vertical. The steel plate forming the test platform was also machined, and these were solidly clamped together. As might be anticipated, the vibrograph records taken under these conditions showed no damping effect.

When the clamps were removed, however, so that the bar was free from the plate, except for the load holding them together, the vibrograph records showed a notable damping effect. In Fig. 11(a) and Fig. 11(b), the load is 156 and 203 lb. per lin. in. of contact, respectively. This indicates that a non-rigid connection between two structural members transmitting load, equivalent to lack of constraint, has a pronounced effect in damping the transmission of vibration between these members. To verify this further, the machined steel bar was replaced by a knife-edge bearing, 4 in. long. The results for a light and a heavy load are shown in Fig. 11(c) and Fig. 11(d).

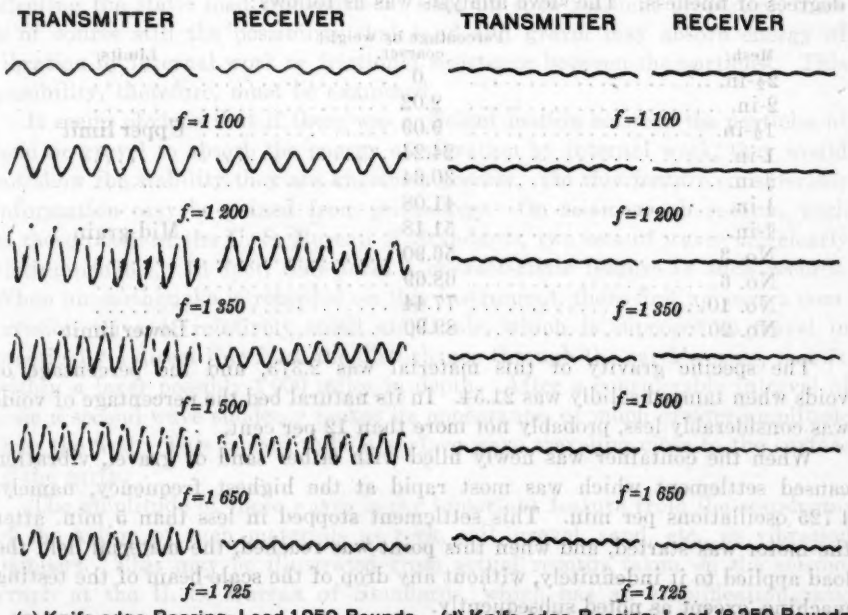
For the light load, the results shown in Fig. 11(a) and Fig. 11(c) are very similar. For the load of 16 250 lb., it is to be noted that the width of the H-beam, or receiver, was 8 in., and, therefore, the load per linear inch in Fig. 11(b) was 2 031 lb., whereas the knife-edge bearing was only 4 in. long, and, consequently, the load in Fig. 11(d) was 4 062 lb. per lin. in. of contact.

In Fig. 11(d) the amplitudes are very much less than in Fig. 11(c), due to the greater load and, consequently, smaller relative effect of the forced vibration. However, the ratios of amplitudes in both diagrams are almost exactly the same, giving an average damping percentage in both cases of 45. The actual numerical value of this damping factor, however, is not of special importance; the chief feature is that damping of a substantial amount results from lack of constraint.

This general principle, that lack of constraint damps the transmission of vibration, may be applied to great advantage in structural design in numerous ways. It also serves to explain the properties of sand and gravel as vibration dampers.



(a) Steel Bar, Free; Load 1250 Pounds (b) Steel Bar, Free; Load 16250 Pounds



(c) Knife-edge Bearing; Load 1050 Pounds (d) Knife-edge Bearing; Load 16250 Pounds

FIG. 11.—VIBROGRAPHS WITH SOLID STEEL PLATE AS INSULATION MEDIUM.

Sand and Gravel

These materials were tested by using sections of iron pipe, 12¼ in. in inside diameter, as containers. Two sections were used, 1 ft. and 2 ft. long, respectively.

The column of sand or gravel rested directly on the test platform. At the upper end a cover-plate rested on the material under test without touching the sides of the pipe. This cover was a cast-iron flange plate, turned down until it fitted the pipe loosely, so that it was supported entirely on the sand or gravel and had no actual contact with the pipe.

The sand tested was of a commercial grade, such as that used in concrete mixtures. The sieve analysis was as follows:

Tyler sieve, No.	Percentage coarser.
4	5
8	13
14	22
28	43
48	83
100	95

The value of the Abrams fineness modulus was 2.65. The gravel tested was obtained from the subway excavation of the terminal improvements of the Pennsylvania Railroad, at Philadelphia, Pa., at sub-grade between Sixteenth and Seventeenth Streets. It was found to be glacial drift, ground up to all degrees of fineness. The sieve analysis was as follows:

Mesh.	Percentage by weight coarser.	Limits.
2½-in.	0	.....
2-in.	2.02	.....
1½-in.	9.09	Upper limit
1-in.	24.24	.....
¾-in.	30.64	.....
½-in.	41.08	.....
⅜-in.	51.18	Mid-grain
No. 3	56.90	.....
No. 6	68.69	.....
No. 10	77.44	.....
No. 20	89.90	Lower limit

The specific gravity of this material was 2.373, and the percentage of voids when tamped solidly was 21.54. In its natural bed the percentage of voids was considerably less, probably not more than 12 per cent.

When the container was newly filled with either sand or gravel, vibration caused settlement which was most rapid at the highest frequency, namely, 1 725 oscillations per min. This settlement stopped in less than 5 min. after the motor was started, and when this point was reached, the material held the load applied to it indefinitely, without any drop of the scale-beam of the testing machine, except as noted subsequently.

However, there was found to be considerable difference in stability between the sand and gravel. When the container was filled with sand, and a cover-

plate 12 in. in diameter was used, leaving a clearance of $\frac{1}{8}$ in. all around between cover and pipe-wall, there was no settlement at the lower frequencies, but, at 1 725 oscillations per min., the sand began to rise through the crack and the cover-plate settled accordingly.

This did not happen with gravel. To test its stability under vibration, a cover-plate only 10 in. in diameter was tried, thus leaving a clearance of $1\frac{1}{2}$ in. all around, between cover and pipe-walls. Although none of the material near the top of the container was larger than $\frac{1}{2}$ to $\frac{3}{4}$ in. in diameter, it showed no tendency to rise through this wide opening or crack, and it was found possible to maintain a constant load at any frequency within the speed limits of the motor. Since the vibrograph records taken did not show any difference between sand and gravel as regards their properties as vibration dampers, the conclusion is that it is advantageous to use gravel rather than sand as sub-foundation material because of its greater stability and because it is less liable to shift and settle under vibration.

As regards vibration properties, sand and gravel are essentially different from materials like cork, rubber, felt, and asbestos. The latter are all compressible and resilient, whereas sand and gravel are incompressible and non-resilient. Referring to the vibrograph records for cork, felt, and rubber (Figs. 3 and 7), it is evident that their action as vibration dampers, or, more properly, as insulators, is due to the fact that they act like a spring, permitting a certain dynamic freedom, or independence, between the two systems, without affecting the static load transmitted. Lacking such resilient properties, there is of course still the possibility that sand and gravel may absorb energy of vibration by internal work or frictional resistance between the particles. This possibility, therefore, must be examined.

It seems obvious that if there was sufficient motion between the particles of sand or gravel to absorb the energy of vibration by internal work, they would not show the stability they are known to possess. On this feature considerable information may be gained from seismology. On seismograph records, such as those taken at the U. S. Bureau of Standards, two sets of waves are clearly distinguishable. In fact, they form a characteristic feature of such records. When an earthquake is recorded on this instrument, there first appears a compression wave of relatively small amplitude, which is supposed to travel in practically a direct line from the disturbance through the earth's crust, that is, within a layer possibly 1 000 miles in depth. After a considerable interval of time a second wave suddenly makes its appearance, of much greater amplitude than the first. This is said to be a surface wave traveling close to the surface of the earth.

The amplitude of these waves is the important feature from the standpoint of the action of such materials as rock, soil, gravel, sand, etc., as vibration dampers. This may be illustrated from actual records taken on the seismograph at the U. S. Bureau of Standards, which has an amplification ratio of 1 000.

For example, the surface wave from an earthquake 2 000 miles distant, traced a graph 4 in. in width. The surface wave from an earthquake under

the Pacific Ocean, 10 000 miles distant, traced a graph fully 1 in. in width. An earthquake in Bulgaria, 7 000 miles distant, traced a graph for the surface wave more than ¾ in. in width.

It would seem to be possible from a comparison of such records to study the damping effect of distance traveled on the amplitude of vibration, but apparently very little has been done along this line. Experimental data obtained during the World War on location of guns by means of soil vibration, indicated that vibration set up by gun-fire was observable for a distance of ¾ mile. In prospecting for oil, soundings are made by noting the time required for vibrations set up by the explosion of a depth charge to reach the surface, but practically no data are available as to the effect of distance traversed on damping the amplitude of vibration. It is sufficiently evident, however, from these and similar instances that within the limited distance of a few feet there can be no marked damping effect due to absorption of the energy of vibration by internal work. Whatever damping properties sand and gravel may possess, therefore, must be independent of the depth of the material within the actual limits usually met in engineering practice.

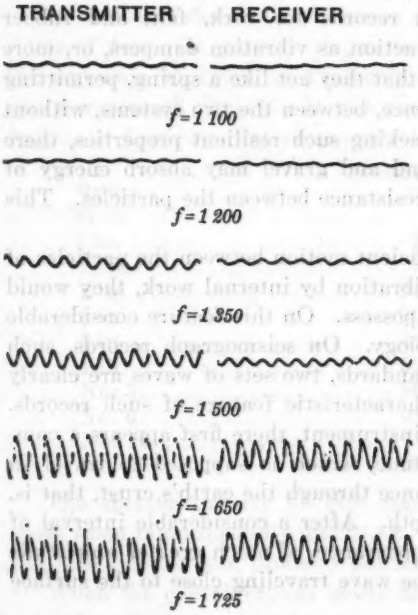


FIG. 12(a).—VIBROGRAPH OF 12-INCH LAYER OF SAND, LOADED TO 19 LB. PER SQ. IN.

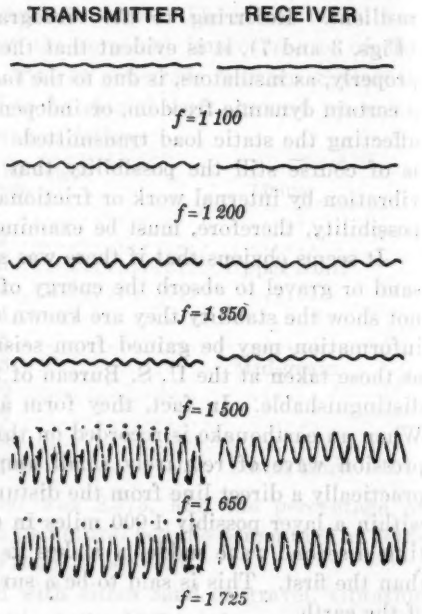


FIG. 12(b).—VIBROGRAPH OF 24-INCH LAYER OF SAND, LOADED TO 19 LB. PER SQ. IN.

In the course of this investigation, however, a large number of vibrograph records were taken with both sand and gravel. Typical results from these tests are shown in Figs. 12 and 13. The general conclusion is that such damping of vibration as results from the use of sand or gravel is a surface effect, similar to that which results from any looseness or lack of rigidity in a struc-

tural connection through which the forced vibration is transmitted. A practical instance of this effect may be noted along any railroad track in the motion of the ties on the ballast when a train passes. Such freedom damps the vibration at the source, localizing the disturbance instead of transmitting it elsewhere, as would be the case if the track were rigidly supported on a steel viaduct or solid masonry.

Mass Damping

Mass may be used as an inertia damper to reduce the amplitude of a forced vibration. For example, in the case of a large Diesel engine, the bed-plate is usually so heavy that no vibration whatever can be felt while standing on it; yet at some point in a structure remote or near-by, there is often a serious vibration. Evidently, this was transmitted from the engine through the bed-plate, but the acceleration it produced in the relatively large mass was so small as to be imperceptible. It re-appears, however, as a large acceleration in some structural member of relatively small mass, the natural frequency of which happens to synchronize with the engine speed.

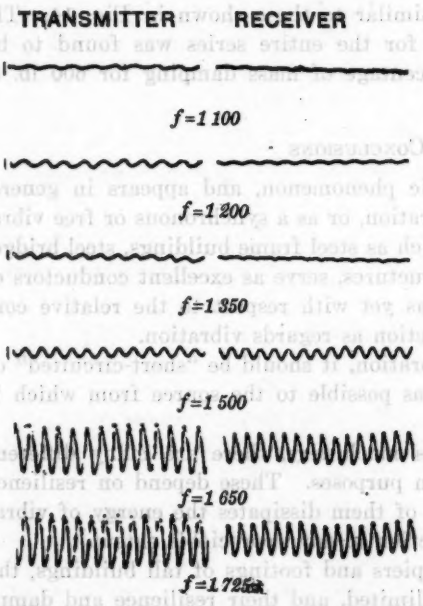


Fig. 13.—Vibrographs of Gravel Sample, 24 In. Deep, Load 19 Lb. per Sq. In.

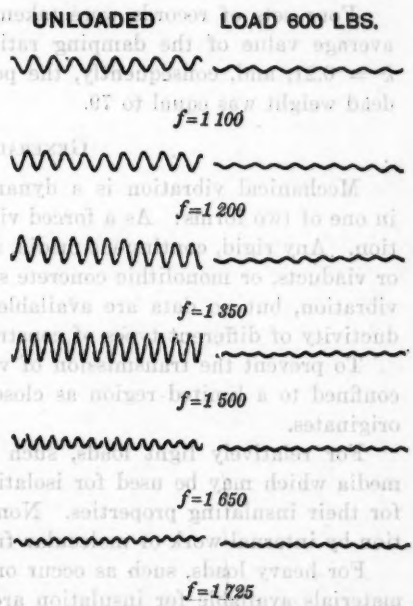


Fig. 14.—Vibrographs Showing Effect of Mass Damping.

It may be noted, however, that when a massive foundation is used under machinery, although apparently it may be effective as a vibration damper, it is not a proper substitute for dynamic balancing because it is inefficient from the standpoint of power losses and strain on the frame of the machine.

With the apparatus used in these tests, the forced vibration was produced by a relatively small mass, namely, the unbalance of the pulley moving at a

high acceleration. The radius of this "unbalance" was $1\frac{3}{4}$ in.; therefore, at the highest speed of 1 725 rev. per min. the centripetal acceleration was:

$$\frac{1.75}{12}\left(\frac{2\,\pi\,1\,725}{60}\right)^2 = 4\,759 \text{ ft. per sec.}$$

The steel, I-beams, motor, and test platform of which the test apparatus was made up, were relatively very heavy with respect to the "unbalance" on the pulley. The acceleration set up in these heavy members was, therefore, relatively small. This is shown in Fig. 14 by the vibrograph records at the left of the diagram, which were taken with the transmitter by itself, with no load on the test platform.

The platform was then loaded with 600 lb. of iron weights, and vibrograph readings taken under this condition, as shown at the right of the diagram. By comparing the two sets it is evident that the amplitude of vibration was greatly reduced by the increase in mass.

Furthermore, it is apparent that the frequency affected the amplitude less, due to the fact that the transmitter by itself has the vibration characteristics of a beam, whereas the iron piled on the test platform possessed only inertia and was not affected by frequency.

Four sets of records were taken similar to those shown in Fig. 14. The average value of the damping ratio for the entire series was found to be, $k = 0.21$, and, consequently, the percentage of mass damping for 600 lb. of dead weight was equal to 79.

General Conclusions

Mechanical vibration is a dynamic phenomenon, and appears in general in one of two forms: As a forced vibration, or as a synchronous or free vibration. Any rigid, continuous media, such as steel frame buildings, steel bridges or viaducts, or monolithic concrete structures, serve as excellent conductors of vibration, but no data are available as yet with respect to the relative conductivity of different types of construction as regards vibration.

To prevent the transmission of vibration, it should be "short-circuited" or confined to a limited region as close as possible to the source from which it originates.

For relatively light loads, such as machinery, there are many different media which may be used for isolation purposes. These depend on resilience for their insulating properties. None of them dissipates the energy of vibration by internal work or molecular friction to any appreciable extent.

For heavy loads, such as occur on piers and footings of tall buildings, the materials available for insulation are limited, and their resilience and damping properties are restricted to relatively narrow limits.

Synchronous vibration may be prevented entirely or eliminated by such modification in the design of the part affected as shall throw its natural frequency out of step with the exciting frequency.

Sand and gravel when used as insulators do not absorb the energy of vibration by internal friction; they owe such effectiveness as they possess to their lack of rigidity. Their insulating property is, therefore, largely a surface effect.

Vibrations of high frequency and relatively small amplitude are the most objectionable from a physiological standpoint.

These tests and such other data as are available, indicate that valuable results may be anticipated from research on the effect of modifying structural detail with a view to damping vibration without recourse to resilient insulators, especially as relates to vibration arising from subway operation and street traffic.

Acknowledgments

The tests on which this study is based, were performed in the Engineering Laboratory of the Towne Scientific School of the University of Pennsylvania. The research facilities of this laboratory were made available through the courtesy of H. C. Berry, M. Am. Soc. C. E. The hair felt used in these tests was a product especially prepared for machinery insulation and was obtained through the courtesy of Mitchells, Ashworth, Stanfield and Company, Ltd., of London, England.

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SPILLWAY DISCHARGE CAPACITY OF WILSON DAM

By Louis G. Puls,* Assoc. M. Am. Soc. C. E.

Synopsis

This paper describes the current-meter discharge measurements made on the spillways at Wilson Dam. The readings were taken for several gate-openings from 3 ft. to full gate and under two conditions, namely, no discharge and full discharge through the adjacent spillways. The head on the crest was 18 ft. Discharge quantities, together with the calculated coefficients for the several partly opened gates and also for full gate, have been obtained.

Introduction

In view of the fact that nearly every dam built recently has an overflow spillway, the discharge of which is controlled by regulating gates of various types, there is a great need for information as to the discharge capacity of these openings. Although experiments have been made and results published on sharp-edged weirs discharging under low heads, very little has been done to supply data as to discharge capacities of spillways with round crests and variable gate-openings under the higher heads, for example, those up to 18.0 ft. It is not a surprising circumstance that such investigations have not been made. Entirely aside from the expense involved, it is not an easy matter to control conditions in order to obtain this information accurately, because a jet of water, 15 ft. in depth, traveling at the rate of 27 ft. per sec., is a rather treacherous mass of energy.

Nevertheless, this work was attempted, inspired by its need and value to hydraulic science, and results have been obtained which are here presented as a pioneering effort.

Description of Spillway

The spillway section consists of a gravity overflow dam with the crest about 80 ft. above the bed of the river. On the crest there are provided fifty-eight

Note.—Written discussion on this paper will be closed in February, 1930, *Proceedings*,

* Care, Hugh L. Cooper & Co., New York, N. Y.

spillway openings formed by the spacing of concrete piers which serve the double purpose of supporting the regulating gates and the arches of a highway bridge. The clear openings are each 38 ft., and the piers are 8 ft. thick. The gates are 39 ft. 3 in. long by 18 ft. high.

The profile of the top of the overflow section, up stream from the seal, has the shape of an ellipse, with the equation, $\frac{x^2}{36} + \frac{y^2}{9} = 1$, the major axis being horizontal and 3 ft. below the crest. (See Fig. 1 (*a*)). The horizontal distance from the up-stream face of the dam to the gate seal is 6 ft. Down stream from the seal the curve is a parabola, with the equation, $42.585\ x = y^2$, the axis of which is vertical and coincides with the minor axis of the ellipse, the origin being at the crest. The up-stream side of the piers is semi-circular in horizontal section, with a radius of 4. ft., that forms a half round nose against the flow of water.

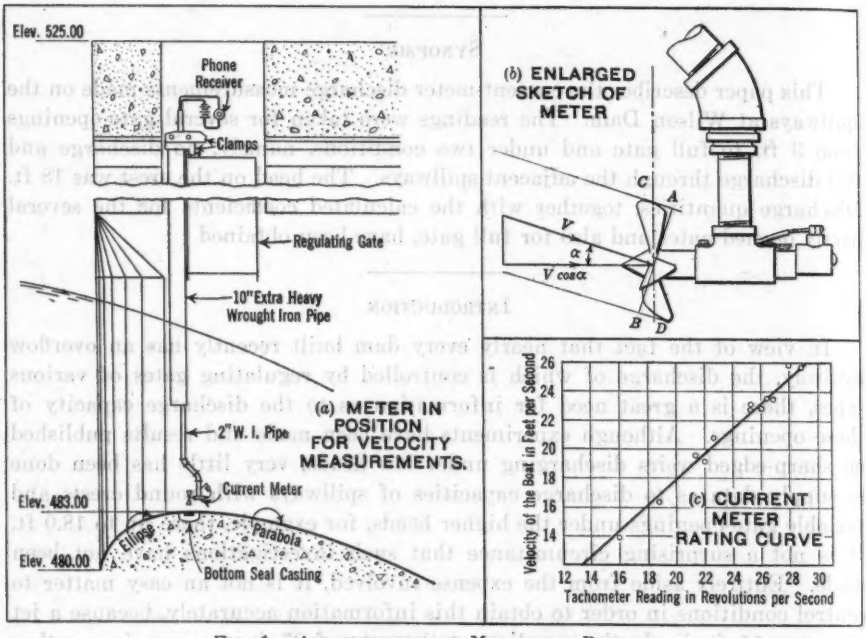

FIG. 1.—ARRANGEMENT OF MEASURING DEVICES.

METHOD OF MEASUREMENT

The Price meters available were designed primarily for comparatively low velocities, up to 4 or 5 ft. per sec. Therefore, it was necessary to construct a meter with bearings capable of withstanding the high velocities of the spillway flow, which are as much as 27 ft. per sec. This meter was designed and built by the writer in the job machine shops. The propeller has three blades, is 4 in. in diameter, and is mounted on a small shaft which has thrust-bearing against the supporting casting. A worm was machined on the end of the shaft, so that it meshed with a wheel, into the face of which was set a small pin.

This pin, in revolving, came in contact with a fine wire terminal and thereby closed a dry-cell battery circuit and caused a clicking sound in the headphone. The ratio of the speed of the propeller to the worm wheel was 20 to 1.

This meter was mounted on the end of a 2-in. wrought-iron pipe in such a manner that the plane of the propeller coincided with the plane of the up-stream side of the gate (see Fig. 1 (*a*).). For all readings at points deeper than 4 ft. in flowing water, a 10-in., extra heavy, wrought-iron pipe supported the 2-in. pipe. In order to place the propeller in the plane over the seal, it was necessary to offset the meter a few inches down stream, and this was done by 1-in. pipe-and-ell fittings connected to the end of the 2-in. pipe (See Fig. 1 (*b*).)

The 2-in. pipe support was sufficiently strong to allow the meter to penetrate 4½ ft. of flowing water. This support was about 32 ft. long and, when placed vertically against the up-stream side of the gate, was held in that position by an iron clamp fastened to the top flange of the gate. This pipe was used also as a conduit for the circuit wires from the meter to the observer on the top of the gate. Readings were taken for various gate-openings at several points in vertical sections of the discharging jet. These sections were located at the center of the spillway opening, at points 8 ft. on either side of the center, and at a point 3 ft. from the side of the opening.

Calibration of Meter

In order to calibrate the meter with a known velocity, it was mounted on the stem of a speed-boat, operating on Lake Wilson. Transits were set up on top of the dam, 1 000 ft. apart, and the telescopes were directed up stream with their lines of sight parallel to each other. The course of the boat was normal to these lines, and the observer on the boat determined the time to travel this 1 000-ft. intercept by means of a stop-watch and signals from the instrument-man. The boat was equipped with a tachometer which indicated the speed of the drive shaft, in revolutions per minute, and this was the only means of holding the boat to a uniform speed. The speed of the current meter was taken for a period of 1 min. These data, plotted to give the relation between revolutions per second of meter to velocity in feet per second of the boat, are shown in Fig. 1 (*c*).

Current Velocity Data

As is customary, the metered results obtained in the field were arranged in tabular form. The gate-opening for each reading was given; and the elevation of pool level, the exact position of the meter in the discharging area and the speed of the propeller were likewise given. From the calibration curve (Fig. 1 (*c*)), the velocity of the water was computed and, finally, this velocity was corrected to give results under a uniform head of 18.0 ft. which placed the pool level at Elevation 501.0 (normal operating pool level).

In these measurements it has been assumed that the velocity as recorded by the meter is the horizontal component of any diagonal flows which may exist. The shaft of the meter was supported as rigidly as possible in a horizontal position. Thus, in Fig. 1 (*b*), it is most reasonable to assume that the velocity

$V \cos \alpha$, multiplied by the area in the plane, $C\,D$, is equal to the velocity, V, multiplied by the area in the plane, $A\,B$. The area in the plane, $C\,D$, is in the vertical plane over the crest.

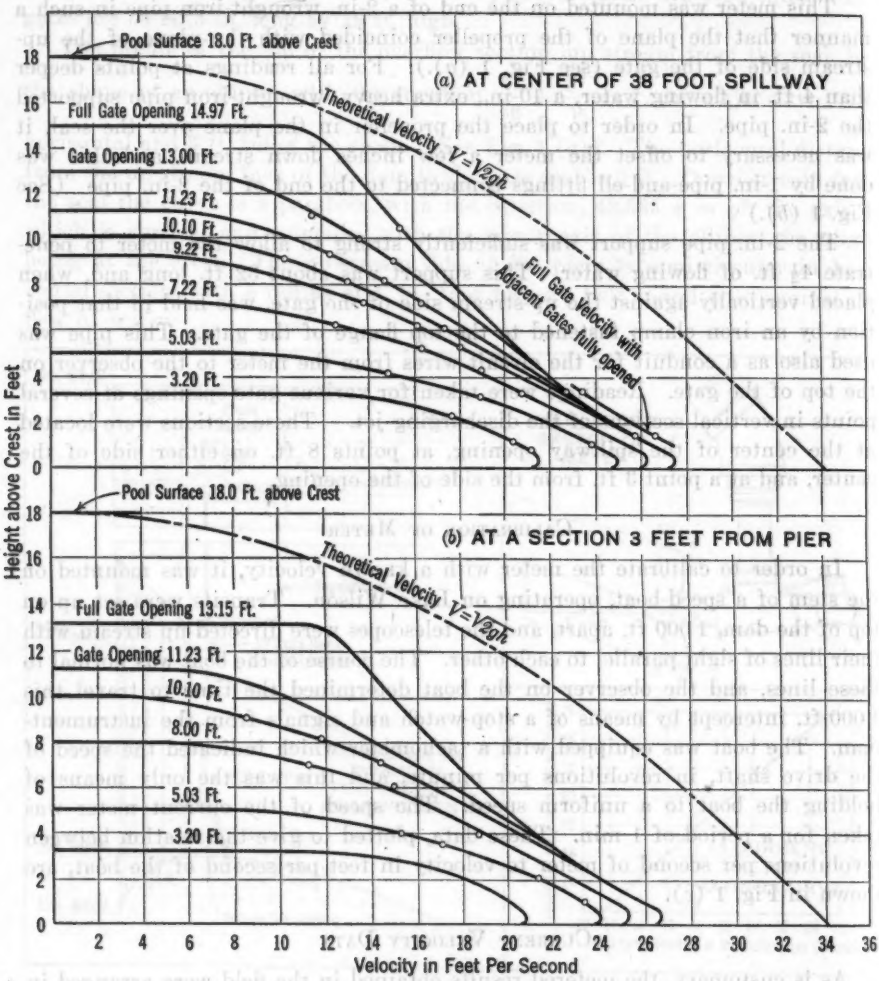
Pool Surface 18.0 Ft. above Crest
(a) AT CENTER OF 38 FOOT SPILLWAY
Full Gate Opening 14.97 Ft.
Theoretical Velocity $V=\sqrt{2gh}$
Gate Opening 13.00 Ft.
11.23 Ft.
10.10 Ft.
9.22 Ft.
7.22 Ft.
5.03 Ft.
3.20 Ft.
Full Gate Velocity with Adjacent Gates fully opened
Pool Surface 18.0 Ft. above Crest
(b) AT A SECTION 3 FEET FROM PIER
Theoretical Velocity $V=\sqrt{2gh}$
Full Gate Opening 13.15 Ft.
Gate Opening 11.23 Ft.
10.10 Ft.
8.00 Ft.
5.03 Ft.
3.20 Ft.
Height above Crest in Feet
0 2 4 6 8 10 12 14 16 18
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36
Velocity in Feet Per Second

FIG. 2.—VERTICAL VELOCITY CURVES.

From the data thus collected curves were drawn showing the relation between gate-opening and the intensity of velocity for various depths below the bottom of the gate. Fig. 2 (*a*) shows the vertical velocity curves for a section at the center of the gate, and Fig. 2 (*b*), those for a section 3 ft. from one end of the spillway.

The areas under the curves of Fig. 2 (*a*) and Fig. 2 (*b*) were measured with a planimeter, and the results obtained were plotted so as to give a curved-line relation between the gate-opening, in feet, and the vertical velocity area, in square feet per second, for the two sections of the discharging jet. That

is, in Fig. 3, the values plotted for the vertical velocity areas are the products of water depth and average velocity for the various gate-openings shown in Fig. 2 (*a*) and Fig. 2 (*b*). Since these points were at odd gate-openings, it was necessary to read from the curves, the velocity areas at openings corresponding to even feet for both sections, in order to integrate for the discharge.

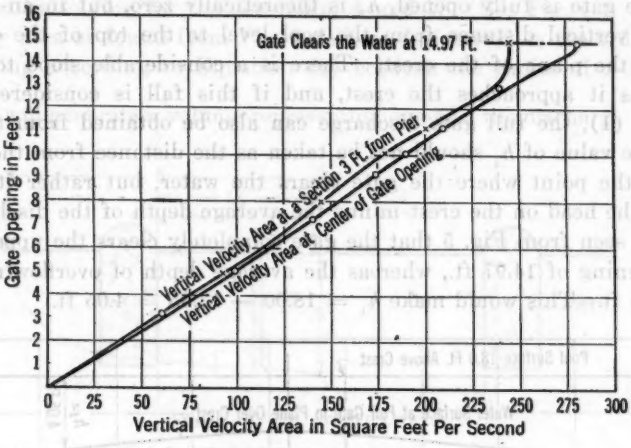
Gate Clears the Water at 14.97 Ft.
Vertical Velocity Area at a Section 3 Ft. from Pier
Vertical Velocity Area at Center of Gate Opening
Gate Opening in Feet
Vertical Velocity Area in Square Feet Per Second
0 25 50 75 100 125 150 175 200 225 250 275 300
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

FIG. 3.—VERTICAL VELOCITY AREA CURVES.

BASIC FORMULA

Fig. 4 illustrates the derivation of the formula for determining the discharge over a spillway with a movable gate. Consider a rectangular orifice of horizontal length, L, and depth, G.

Let h_1 = head on the upper edge.
h_2 = head on the lower edge.
dF = area of a differential element of the cross-section.
z = head on the element, dF.
dq = differential discharge.

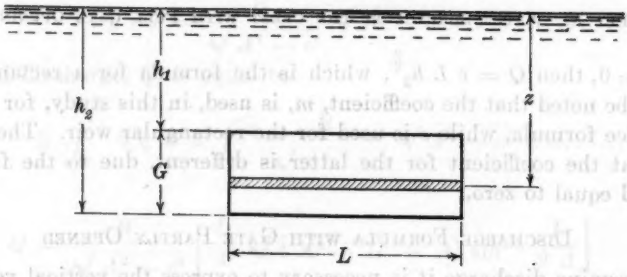

FIG. 4.

Then, $dq = \sqrt{2g}\, z\, dF$, and the discharge for the entire orifice is the integral of this expression for the entire area, F. Therefore,

$$Q = \sqrt{2g}\, L \int_{h_1}^{h_2} z^{\frac{1}{2}}\, dz = \frac{2}{3}\sqrt{2g}\, L \left(h_2^{\frac{3}{2}} - h_1^{\frac{3}{2}} \right)$$

For the actual case, the rate of discharge is founded by applying a coefficient to this ideal value. The result may be written,

$$Q = m\,L\left(h_2^{\frac{3}{2}} - h_1^{\frac{3}{2}}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

This is the basic formula. When the gate is closed, $h_1 = h_2$ and $Q = 0$. When the gate is fully opened, h_1 is theoretically zero, but in an actual case it is the vertical distance from the pool level to the top of the discharging water in the plane of the crest. There is a considerable slope to the water surface as it approaches the crest, and if this fall is considered as h_1 in Equation (1), the full gate discharge can also be obtained from this expression. The value of h_1 should not be taken as the distance from the pool level down to the point where the gate clears the water, but rather it should be equal to the head on the crest minus the average depth of the discharging jet. It will be seen from Fig. 5 that the gate completely clears the upper nappe at a gate-opening of 14.97 ft., whereas the average depth of overflowing water is only 13.95 ft. This would make $h_1 = 18.00 - 13.95 = 4.05$ ft.

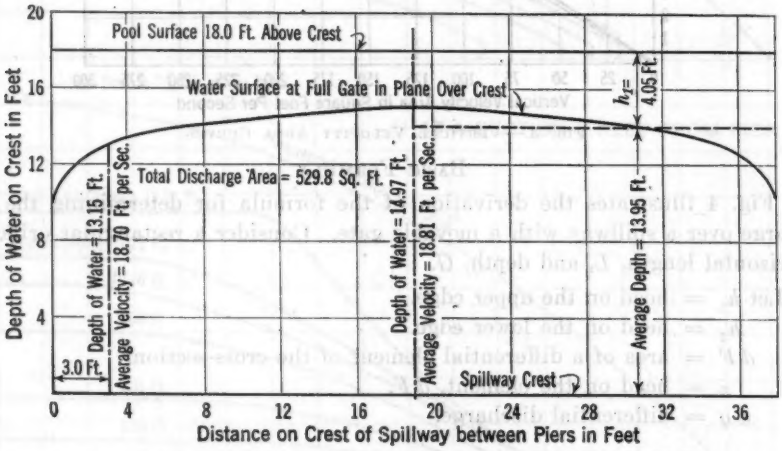

FIG. 5.—WATER SURFACE AT THE CREST WITH FULL GATE OPENING.

If $h_1 = 0$, then $Q = c\,L\,h_2^{\frac{3}{2}}$, which is the formula for a rectangular weir. It should be noted that the coefficient, m, is used, in this study, for the rectangular orifice formula, while c is used for the rectangular weir. The reason for this is that the coefficient for the latter is different, due to the fact that h_1 is assumed equal to zero.

DISCHARGE FORMULA WITH GATE PARTLY OPENED

To determine discharge it is necessary to express the vertical velocity area as a function of the length of the spillway and to integrate between the limits of this length. Since it varies from the pier to the center of the gate-opening, the vertical velocity area can be expressed as a function of this distance by the equation of an ellipse. No doubt there is a rapid decrease in the rate of change in this area within a few inches from the masonry pier and conse-

quently the curve departs from any definite function of the spillway length. However, the percentage of error is small and can be neglected.

The equation of the ellipse:

$$\frac{x^2}{A^2} + \frac{y^2}{b^2} = 1 \quad \ldots\ldots (2)$$

is established by solving for the constants, A and b. (See Fig. 6.) The vertical velocity area as found from Fig. 3, is here designated as the ordinate, A, and in moving according to Equation (2) between the limits of $x = 0$ and $x = \frac{L}{2}$, it will generate a volume representing one-half the discharge.

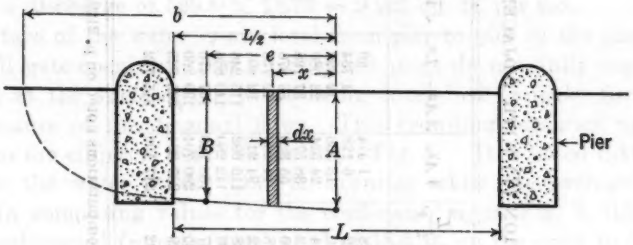

FIG. 6.—PLAN OF SPILLWAY.

When $x = e$, $y = B$, and Equation (2) may then be written:

$$b^2 = \frac{B^2}{1 - \frac{e^2}{A^2}} \quad \ldots\ldots (3)$$

Substituting this value of b^2 in the general formula (Equation (2)), and solving for y:

$$y = \frac{B}{\sqrt{A^2 - e^2}} \sqrt{A^2 - x^2} \quad \ldots\ldots (4)$$

The differential discharge, $d\,q$, is equal to,

$$y\,d\,x = \frac{B}{\sqrt{A^2 - e^2}} \sqrt{A^2 - x^2}\,d\,x \quad \ldots\ldots (5)$$

and the total discharge, Q, is equal to:

$$2\int_0^{\frac{L}{2}} d\,q = 2\int_0^{\frac{L}{2}} \frac{B}{\sqrt{A^2 - e^2}} \sqrt{A^2 - x^2}\,d\,x \quad \ldots\ldots (6)$$

or,

$$Q = \frac{B}{\sqrt{A^2 - e^2}} \left[\frac{L}{4}\sqrt{4\,A^2 - L^2} + A^2 \sin^{-1}\frac{L}{2\,A}\right] \quad \ldots\ldots (7)$$

In the special problem under discussion, e and L (see Fig. 6) are constant; that is, $L = 38$ ft. and $e = \frac{38}{2} - 3 = 16$ ft.

Computations for the discharge through each foot of gate-opening are arranged as shown in Table 1. The values of the areas, A and B, are taken

TABLE 1.—COMPUTATION TABLE FOR THE SOLUTION OF EQUATION (7) WITH ADJACENT GATES CLOSED.

Gate opening, in feet.	A.	B.	A^2.	$A^2 - e^2$.	$\sqrt{A^2 - e^2}$.	$\frac{B}{\sqrt{A^2 - e^2}}$.	$\sin^{-1} \frac{L}{2A}$.	$A^2 \sin^{-1} \frac{L}{2A}$.	$4A^2$.	$4A^2 - L^2$.	$\sqrt{4A^2 - L^2}$.	$\frac{L}{4}\sqrt{4A^2 - L^2}$.	Q, in cubic feet per second.
1	19.2	19.0	368.6	112.6	10.6	1.79	1.481	526	1 474	30	5.5	52.8	1 039
2	39.3	38.2	1 544.5	1 288.5	35.9	1.06	0.506	782	6 178	4 734	68.8	653.6	1 523
3	58.6	57.2	3 434.0	3 178.0	56.4	1.01	0.339	1 140	13 736	12 292	110.9	1 053.6	2 214
4	78.3	77.0	6 130.9	5 874.9	76.6	1.00	0.247	1 514	24 524	23 080	152.0	1 444.0	2 958
5	98.2	96.0	9 643.2	9 387.2	96.9	0.99	0.191	1 843	38 572	37 128	192.8	1 831.6	3 640
6	117.6	114.0	13 829.8	13 573.8	116.5	0.98	0.159	2 200	55 320	53 876	232.2	2 205.9	4 325
7	136.2	130.6	18 550.4	18 294.4	135.2	0.97	0.139	2 578	74 200	72 756	270.0	2 565.0	4 990
8	153.5	145.6	23 562.3	23 306.3	152.7	0.96	0.124	2 922	94 248	92 804	302.6	2 874.7	5 565
9	170.8	160.6	29 172.6	28 916.6	170.2	0.94	0.111	3 238	116 692	115 248	339.8	3 228.1	6 080
10	188.6	178.0	35 570.0	35 314.0	188.0	0.95	0.101	3 593	142 280	140 836	375.2	3 564.4	6 800
11	205.5	197.0	42 230.3	41 974.3	205.0	0.96	0.093	3 927	168 920	167 476	409.0	3 885.5	7 510
12	224.0	216.5	50 176.0	49 920.0	223.6	0.97	0.085	4 265	200 704	199 260	446.5	4 241.8	8 260
13	243.6	236.5	59 341.0	59 085.0	243.0	0.97	0.078	4 629	237 364	235 920	486.0	4 617.0	8 960
Full gate....	261.6	245.9	79 298.6	79 042.6	281.2	0.88	0.068	5 392	317 196	315 752	562.0	5 339.0	9 450 9 925*

*This corrected figure is obtained from average velocity computations noted on p. 2139.

from Fig. 3. It will be noted that Table 1 gives the discharge for full gate-opening to be 9 450 cu. ft. per sec., as computed by Equation (7). For this particular opening, the elliptical curve integration may give a result less than the actual due to the greater difference in the velocity areas, A and B. If the velocity area at A is divided by the depth of the water at that point (see Fig. 5), the average velocity for the section is $\frac{281.6}{14.97} = 18.8$ ft. per sec. Similarly, the average velocity for the section, B, is $\frac{245.9}{13.15} = 18.7$ ft. per sec. This shows the average velocity to be nearly equal in the two sections. The total area of the discharging jet at full gate is 529.8 sq. ft. (See Fig. 5.) This would give a discharge of $529.8 \times 18.75 = 9\,925$ cu. ft. per sec.

The surface of the water is not level from pier to pier in the plane of the crest at full gate-opening. The round-nosed piers do not fully suppress the contraction at the surface, the water being compelled to make further contraction because of the diagonal flows. This crowding tendency toward the center forms the elliptical curve as shown in Fig. 5. It is noted that the gate would clear the water at the 14.97-ft. opening, while the average depth is 13.95 ft. In computing values for the coefficient, m, in Fig. 7, this average depth was subtracted from the total head of 18.0 ft. on the crest to obtain the value of h_1, which is 4.05 ft. This is why it has been correlated to "Average Depth of Discharging Jet" instead of "Gate Opening". The coefficient, m, was computed for these conditions by Equation (1). The points were then plotted as shown in Fig. 7 and a smooth curve was drawn through them. Revised ideal coefficients were then read from the smooth curve and the final discharge values were computed from them. The coefficient, c, in the Francis formula, corresponding to this coefficient, m, is 3.420 for full-gate discharge.

The discharge curves on Fig. 7 are plotted against gate-openings, thereby giving the maximum discharge at the instant the gate clears the water. As the gate rises through the upper 12 in. of flowing water, the tangent of the curve rapidly approaches infinity, and the increment of discharge becomes less for any increment of gate-opening until the gate clears the water, beyond which instant obviously the increment of discharge is zero.

Discharge Capacity of Spillway with Adjacent Gates Open

The discharge of one spillway is increased materially if the adjacent openings are discharging at the same time. This increase in quantity discharged can be treated as if it were due to an increment of head. Thus, if the head, H, produces a discharge, Q, with adjacent gates closed, $H + \Delta h$ will produce $Q + \Delta q$ with them opened, wherein Q can have, without appreciable error, the same ratio to $Q + \Delta q$ as the ratio of the three halves power of the heads, or,

$$\frac{Q}{Q + \Delta q} = \left(\frac{H}{H + \Delta h}\right)^{\frac{3}{2}}.$$

Since the values of H and Q are known (see Table 1), it remains to find $H + \Delta h$ before it is possible to solve for $Q + \Delta q$. In order to determine the

head, $H + \Delta h$, it is only necessary to meter the velocity at a short distance above the crest, and then solve for the increment of head necessary to increase the velocity curve, under the condition of adjacent gates closed, to coincide with the metered points under the condition with the adjacent gates opened.

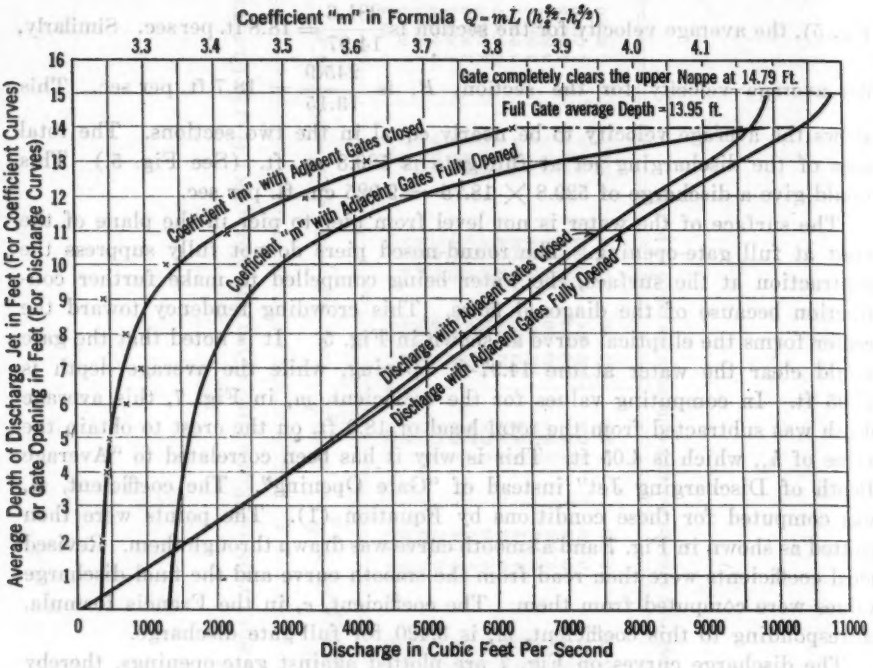

FIG. 7.—COEFFICIENT AND DISCHARGE CURVES.

At the center of the spillway, with full gate-opening, at an elevation of 2.0 ft., above the crest, the velocity is 24.8 ft. per sec. under the first condition and 25.6 ft. per sec. under the second condition (see Fig. 2 (*a*)). Since the head of 16.0 ft. produced the velocity of 24.8 ft. per sec., a head of $16\left(\frac{25.6}{24.8}\right)^2 = 17.08$ ft. may be expected to produce the velocity of 25.6 ft. per sec. This is equivalent to raising the pool level to 17.08 + 2.0 = 19.08 ft. above the crest instead of 18.0 ft. as in the first condition. It follows that the effect on the discharge of the intermediate spillway of opening the neighboring gates fully, is similar to that of raising the pool 1.08 ft.

By using the formula,

$$Q' = Q\,\frac{h_4^{\frac{3}{2}} - h_3^{\frac{3}{2}}}{h_2^{\frac{3}{2}} - h_1^{\frac{3}{2}}} \qquad (8)$$

in which, Q' equals $Q + \Delta q$ and h_4 equals $H + \Delta h$, the discharge, Q', can be found because all other values are now known. Equation (8) holds good not only for full gate-opening, but also for gates partly opened, in which the

values of h_3 and h_1, the respective heads on the top of the jet, must be introduced.

The curves of Equation (8) are plotted in Fig. 7 for the two conditions: Adjacent gates closed and fully opened. By picking the proper discharge values from these curves, the corresponding values of m may be determined by making the necessary substitutions in Equation (1). The corresponding, deduced coefficient, c, in the Francis formula for full gate discharge, is 3.738.

Discharge of One Opening Under Condition of Adjacent Gates Partly Opened

Fig. 7 shows the discharge of one opening under the conditions that both adjacent gates are either closed or fully opened. Although no measurements were made when one adjacent gate was open and the other closed, it is reasonable to assume that, under this condition, the discharge would be the mean of those determined from the two curves. Thus, if one adjacent gate were closed and the other fully open, the discharge of the intermediate 8.0-ft. opening would be $\frac{5\,583 + 5\,801}{2} = 5\,692$ cu. ft. per sec.

If the adjacent gates were open a small distance compared to the intermediate gate, the effect on the discharge of the latter, no doubt, would be negligible.

If the adjacent gates were each opened as much as the intermediate gate, the effect would be slightly less than under the condition of adjacent gates fully opened, because every particle of water in the neighboring regions for the depth of the opening is in motion and, therefore, the retarding influence is removed.

Total Spillway Capacity of Wilson Dam

With adjacent gates fully opened, the discharge of one 38-ft. spillway under a head of 18 ft. on the crest at full gate, is 10 848 cu. ft. per sec. This would give a total spillway capacity of 10 848 $\times$ 58 (number of 38-ft. openings) = 629 184 cu. ft. per sec. Furthermore, if two or more gates were open on both sides of any discharging opening, this condition would increase the capacity of the latter slightly. There is a limit no doubt to this increased discharge effect by opening more gates. Perhaps the effect would not be appreciable beyond two, but, regarding this limit, no information on which calculations can be based, is available.

Comparison Between Florence Gauge Rating and Wilson Dam Spillway Gate-Opening Rating

The United States Geological Survey gauge at the Florence Bridge is located about 3 miles down stream from the Wilson Dam. This offers an opportunity to make comparative calculations of the Tennessee River discharge. The Florence gauge was established in 1871 and a rating curve has been used for it since 1894. The control at the section is considered practically permanent. On this rating curve appear approximately 120 points indicating current-meter measurements taken from a range of 8 000 to 319 000 sec-ft.

For the purpose of comparison, data were taken from the records of the plant at Wilson Dam over a period such that the discharge ranged from 19 000 to 345 000 cu. ft. per sec., using twenty-four different flows within this range. These data included: (1) The setting of each of the fifty-eight spillway gates; (2) the trash chute opening; and (3) the quantity of water passing through the turbines based upon power-discharge curves. From these data, the total discharge of the river was determined, using the foregoing rating for the spillways (see Fig. 7). The Florence gauge discharges were taken from the official river records for the exact time when the recorded flows at Wilson Dam reached the gauge. Points were selected only when the gauge showed a constant reading for six hours. This allowed ample time for travel between the stations.

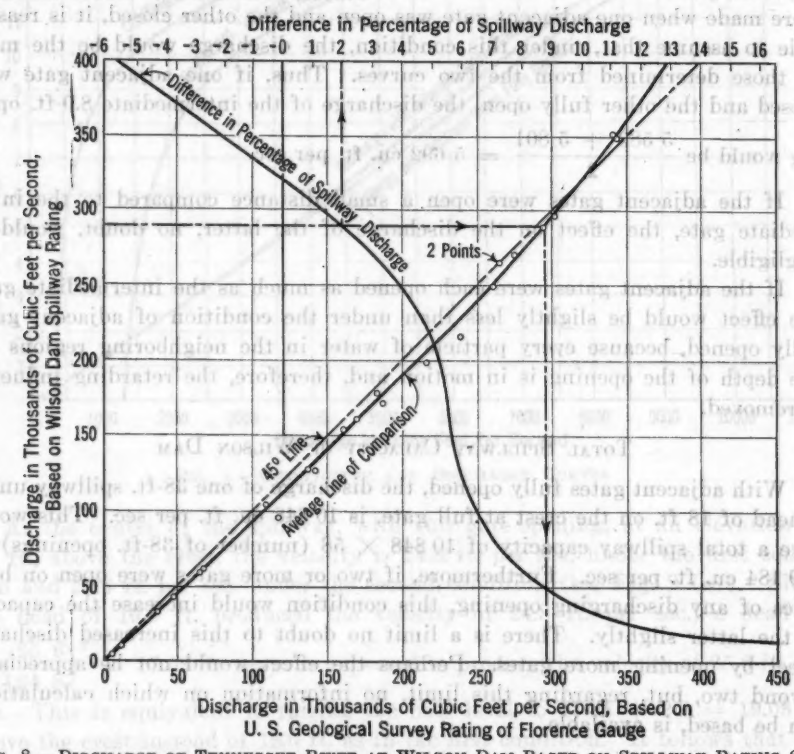
Difference in Percentage of Spillway Discharge
-6 -5 -4 -3 -2 -1 -0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Difference in Percentage of Spillway Discharge
2 Points
45° Line
Average Line of Comparison
Discharge in Thousands of Cubic Feet per Second, Based on Wilson Dam Spillway Rating
400
350
300
250
200
150
100
50
0
0 50 100 150 200 250 300 350 400 450
Discharge in Thousands of Cubic Feet per Second, Based on U. S. Geological Survey Rating of Florence Gauge

FIG. 8.—DISCHARGE OF TENNESSEE RIVER AT WILSON DAM BASED ON SPILLWAY RATING COMPARED WITH DISCHARGE AT FLORENCE GAUGE BASED ON U. S. GEOLOGICAL SURVEY RATING.

The data for the spillway computations are shown in Table 2. These discharges were listed in Table 3 and were added to the discharges through the turbines and trash chute, thereby giving the total flow past the dam. The official gauge heights and discharge rating of the Florence gauge are also included in Table 3 for purposes of comparison.

It will be noted that in all but the last two instances the discharge as shown by the Florence gauge rating is greater than that by the spillway

TABLE 2.—DISCHARGE MEASUREMENTS OF TENNESSEE RIVER AT WILSON DAM.

Date.	Time.	Head on crest, in feet.	Gate-opening, in feet.	Number of gates open.	Discharge for one gate, in cubic feet per second.	Discharge for total number of gates, in cubic feet per second.	Total discharge of spillway, in cubic feet per second.
September 16, 1926.....	10:00 P. M.	17.33	0.5	11	390	4 290	4 290
September 10, 1926.....	4:00 P. M.	17.49	0.5	4	392	1 568	
			1.0	11	784	8 624	10 192
August 24, 1926.....	11:00 P. M.	17.40	3.0	3	2 281	6 843	
			4.0	12	2 997	35 964	42 807
December 10, 1926.....	8:00 A. M.	17.94	2.5	4	1 941	7 764	
			3.0	7	2 317	16 219	
			3.5	2	2 682	5 364	
			4.0	1	3 046	3 046	32 393
February 2, 1927.....	2:00 A. M.	17.11	2.0	2	1 528	3 056	
			6.5	6	4 650	27 900	
			7.0	6	4 974	29 844	60 800
February 8, 1927.....	8:00 P. M.	17.10	1.0	1	774	744	
			1.5	1	1 151	1 151	
			2.0	1	1 528	1 528	
			6.5	12	4 650	55 800	59 253
February 21, 1927.....	4:00 A. M.	17.05	1.5	1	1 150	1 150	
			2.0	2	1 528	3 056	
			3.0	1	2 258	2 258	
			4.0	9	2 968	26 712	
			8.0	11	5 607	61 677	94 853
February 16, 1927.....	8:00 P. M.	17.11	1.5	1	1 150	1 150	
			2.0	2	1 528	3 056	
			5.5	8	3 992	31 736	
			8.0	12	5 607	67 284	103 226
February 24, 1927.....	10:00 P. M.	17.14	1.5	1	1 150	1 150	
			2.0	2	1 528	3 056	
			3.0	1	2 258	2 258	
			8.0	17	5 607	95 319	
			9.0	4	6 280	24 920	126 703
December 17, 1926.....	12:00 Midnight	17.88	1.5	1	1 178	1 178	
			2.0	2	1 566	3 132	
			5.0	6	3 758	22 548	
			6.0	8	4 446	35 568	
			8.0	11	5 778	63 558	125 984
February 28, 1927.....	3:00 A. M.	17.18	1.5	1	1 155	1 155	
			2.0	2	1 533	3 066	
			3.0	1	2 266	2 266	
			7.0	5	4 992	24 960	
			8.0	8	5 629	45 032	
			12.0	10	8 305	83 050	159 529
February 27, 1927.....	8:00 A. M.	17.15	1.5	1	1 155	1 155	
			2.0	2	1 533	3 066	
			3.0	1	2 266	2 266	
			4.0	1	2 977	2 977	
			8.0	12	5 629	67 548	
			11.0	10	7 565	75 650	152 662
March 16, 1927.....	12:00 Noon	17.11	2.0	1	1 528	1 528	
			4.0	16	2 968	47 488	
			8.0	8	5 607	44 856	
			11.0	7	7 531	52 717	
			12.0	3	8 266	24 798	171 387
March 12, 1927.....	10:00 A. M.	17.18	2.0	10	1 528	15 280	
			3.0	1	2 258	2 258	
			5.0	1	3 659	3 659	
			6.0	1	4 325	4 325	
			8.0	11	5 607	61 677	
			13.0	10	9 071	90 710	177 909

TABLE 2.—(*Continued*).

Date.	Time.	Head on crest, in feet.	Gate-opening, in feet.	Number of gates open.	Discharge for one gate, in cubic feet per second.	Discharge for total number of gates, in cubic feet per second.	Total discharge of spillway, in cubic feet per second.
December 25, 1926.....	6:00 P. M.	17.94	3.0	1	2 317	2 317	
			4.0	1	3 046	3 046	
			8.0	14	5 778	80 892	
			Full	12	10 757	129 084	215 399
March 15, 1927.....	5:00 P. M.	17.09	2.0	1	1 528	1 528	
			4.0	10	2 968	29 680	
			5.0	6	3 659	21 954	
			8.0	8	5 607	44 856	
			Full	10	10 044	100 440	198 458
January 4, 1927.....	5:00 P. M.	17.65	3.0	3	2 303	6 909	
			4.0	1	3 026	3 026	
			5.0	2	3 734	7 468	
			8.0	9	5 737	51 633	
			Full	19	10 578	200 982	270 018
December 27, 1926.....	9:00 A. M.	17.68	3.0	1	2 303	2 303	
			4.0	1	3 026	3 026	
			8.0	10	5 737	57 370	
			Full	19	10 578	200 982	263 681
December 26, 1926.....	8:00 A. M.	17.67	3.0	1	2 303	2 303	
			4.0	1	3 026	3 026	
			8.0	11	5 737	63 107	
			Full	17	10 578	179 826	248 262
December 27, 1926.....	5:00 P. M.	17.66	3.0	1	2 303	2 303	
			4.0	1	3 026	3 026	
			8.0	10	5 737	57 370	
			Full	19	10 578	200 982	263 681
March 13, 1927.....	2:00 P. M.	17.31	2.0	1	1 538	1 538	
			4.0	14	2 988	41 832	
			6.0	6	4 355	26 130	
			8.0	2	5 651	11 302	
			10.0	3	6 922	20 766	
			Full	19	10 221	194 199	295 767
January 3, 1927.....	5:00 A. M.	17.72	3.0	3	2 303	6 909	
			4.0	1	3 026	3 026	
			5.0	2	3 734	7 468	
			8.0	6	5 737	34 422	
			10.0	2	7 036	14 072	
			Full	21	10 578	222 138	288 035
December 29, 1926.....	4:00 P. M.	17.78	4.0	17	3 037	51 629	
			5.0	5	3 747	18 735	
			8.0	4	5 758	23 032	
			10.0	2	7 065	14 130	
			12.0	2	8 537	17 074	
			Full	21	10 668	224 028	348 628
December 30, 1926.....	10:00 P. M.	17.68	4.0	11	3 026	33 286	
			5.0	11	3 734	41 074	
			8.0	4	5 737	22 948	
			10.0	2	7 036	14 072	
			12.0	2	8 499	16 998	
			Full	21	10 578	222 138	350 516

rating. The discharges in Columns (2) and (3) of Table 3 were deducted from those in Column (6) and the net quantities were plotted against corresponding values in Column (1), to give the average relation line as shown on Fig. 8. By drawing the 45° line, which would be the locus of all the points if the two methods checked exactly, it will be seen that the actual average relation line is below the 45° line from zero to 320 000 cu. ft. per sec., and there it crosses

and remains above it. Calculating the ordinate intercept between these two lines in percentage of the spillway discharge and plotting this percentage to the latter quantity, gives the compound curve marked, "Difference in Percentage of Spillway Discharge", part of which is negative and part positive.

TABLE 3.—DISCHARGE OF TENNESSEE RIVER AT WILSON DAM BASED UPON THE SPILLWAY RATING IN COMPARISON WITH THE DISCHARGE AT FLORENCE GAUGE BASED UPON THE UNITED STATES GEOLOGICAL SURVEY RATING.

Discharge of spillway taken from Table 2, in cubic feet per second. (1)	Discharge of trash chute, in cubic feet per second. (2)	Discharge of turbines, in cubic feet per second. (3)	Total discharge at Wilson Dam, in cubic feet per second. (4)	Florence gauge, in feet. (5)	Discharge on U. S. Geological Survey rating, in cubic feet per second. (6)
4 290	310	12 905	17 505	1.42	19 100
10 192	310	9 777	20 279	1.76	21 200
32 393	890	12 943	46 226	5.31	49 600
42 807	0	4 790	47 597	5.52	51 500
60 800	635	14 796	76 231	8.45	82 000
59 253	635	14 720	74 608	8.32	80 600
94 853	635	108	95 596	11.40	118 000
103 226	635	9 344	113 205	11.40	118 000
126 708	635	574	127 912	12.95	138 500
125 984	890	97	126 971	13.20	141 500
159 529	635	108	160 272	15.25	170 000
152 662	635	97	153 394	14.65	160 400
171 387	1 475	7 195	180 057	17.00	195 900
177 909	635	6 007	184 551	16.62	189 200
215 339	890	137	216 366	19.91	239 600
198 458	1 475	7 192	207 125	18.98	225 000
270 018	890	4 385	275 293	22.60	280 500
263 681	890	1 838	266 409	22.04	268 200
248 262	890	97	249 249	21.34	261 500
263 681	890	447	265 018	21.67	266 000
295 767	635	380	296 782	23.91	303 200
288 035	890	3 487	292 412	23.40	295 400
348 628	890	2 285	351 803	26.51	346 000
350 516	890	561	351 967	26.35	343 100

To illustrate its use in comparing the two sets of data, consider a spillway discharge of 290 000 cu. ft. per sec. A horizontal line from 290 intersects the percentage curve at 2, so that the corresponding discharge, determined by the Florence gauge rating, would be $290\,000 + 0.02 \times 290\,000 = 295\,800$ cu. ft. per sec. This value may be checked by producing the horizontal line to intersect the average curve of comparison. The example here given excludes consideration of discharges through trash chute or turbines which must naturally be added to the quantity resulting from the use of Fig. 8.

ACKNOWLEDGMENT

This study of spillway discharge was made possible only by the generous interest and co-operation of Capt. Hugh P. Oram, Corps of Engineers, U. S. Army, District Engineer, Florence, Ala., who authorized both the time of the personnel and the use of equipment necessary for making the tests.

AMERICAN SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

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ESSENTIAL FACTS CONCERNING THE FAILURE OF THE ST. FRANCIS DAM

REPORT OF COMMITTEE OF BOARD OF DIRECTION

THE PRESIDENT AND BOARD OF DIRECTION,
AMERICAN SOCIETY OF CIVIL ENGINEERS.

GENTLEMEN.—On April 24, 1928, the Board of Direction authorized the appointment of a committee of three to compile for the information of the membership of the Society, the essential facts disclosed in the various official committee reports made in connection with the failure of the St. Francis Dam in California. The Committee has confined its report to the consideration of such official committee reports, but it directs attention to the fact that, without being official, inspections of the structure were made by many engineers and geologists who contributed valuable articles in the technical press. The Committee has not attempted to list or abstract these articles, but refers the membership to the various engineering indices.

Attached is the report of the Committee.

Yours very truly,
LOUIS C. HILL,
H. W. DENNIS,
F. H. FOWLER.

August 16, 1929.

GENERAL DESCRIPTION OF THE DAM AND ITS COLLAPSE

The St. Francis Dam was constructed between April, 1924, and May, 1926, by the Bureau of Water-Works and Supply, City of Los Angeles, Calif., on San Francisquito Creek and along the Los Angeles Aqueduct about forty miles north of the city; it failed at midnight, March 12, 1928.

The dam was of the gravity type, was arched on a radius of 500 ft. to the up-stream face of the crest, and was 700 ft. long. At its westerly end a wing-wall continued along the crest of a narrow ridge, finally terminating at a knoll about 500 ft. from the end of the main dam; a small gap beyond

NOTE.—Written discussion of this report is requested and will be published in subsequent numbers of *Proceedings*.

this knoll was closed by a low concrete wall. The main dam was 205 ft. high, 16 ft. thick at the crest, and 176 ft. thick at the base. The down-stream face was carried up in steps uniformly 5 ft. high, but varying in width. There were no vertical contraction joints. Fig. 1 shows a plan of the dam, and Fig. 2, the maximum section.

The conditions of design are summarized as follows:

(*a*) Formulas used are given in "Masonry Dam Design" by Morrison and Brodie (Second Edition). Overturning moment due to horizontal water pressure only was considered.
(*b*) No allowance made for free-board.
(*c*) Pressure on toe of dam, or down-stream face, p, limited to 20 000 lb. per sq. ft.
(*d*) Pressure on heel of dam, or up-stream face, q, limited to 24 000 lb. per sq. ft.
(*e*) Unit weight of concrete, 140 lb. per cu. ft.
(*f*) Unit weight of water, 62.5 lb. per cu. ft.
(*g*) Dam designed as gravity section without considering any arch action.

Eleven spillway openings, each 20 ft. wide and 1.5 ft. in clear depth, were located in two groups near the center of the dam. Five outlet pipes, each 30 in. in diameter, at vertical intervals of about 36 ft., were controlled by sliding gates.

The elevation of the crest of the parapet was 1 838.06 ft., of the crest of the spillway lip, 1 835.00 ft., and of the bottom of the maximum section, 1 630.00 ft.

The foundation excavation in the bottom of the canyon, up the westerly side, and under the wing-wall, was carried out chiefly by sluicing and by steam shovel. Up the easterly side of the canyon, which was much steeper, the abutment was prepared by notching into the rock of the canyon wall, carrying the concreting up with the excavation, along the natural planes of the rock in the abutment, and without cutting horizontal steps.

The foundation material from the easterly end of the dam down to and across the main channel and about half way up the west side, was laminated mica schist, the dip of which approximated the slope of the east abutment, and the strike was almost normal to the long chord of the arch. About half way up the west abutment there was a contact and fault between this mica schist and a dark reddish conglomerate, which composed all the remaining portion of the main dam site and the westerly ridge.

No cut-off wall was constructed under the up-stream face of the dam, but a small key-wall not more than 3 by 3 ft. at any place was cut into the schist and conglomerate up along the west abutment about 25 ft. from the up-stream face of the dam, and a very shallow cut-off wall was carried along the upper side of the wing-wall. No grouting was done at any point in the foundations. No provisions were made to relieve uplift except that in the bottom of the canyon ten holes in two lines were bored to depths variously reported to have been from 20 to 30 ft., and cross-connected to a central outlet.

Tests of the concrete show it to have been satisfactory. It is stated that 1.12 bbl. of Portland cement were used per cubic yard of concrete.

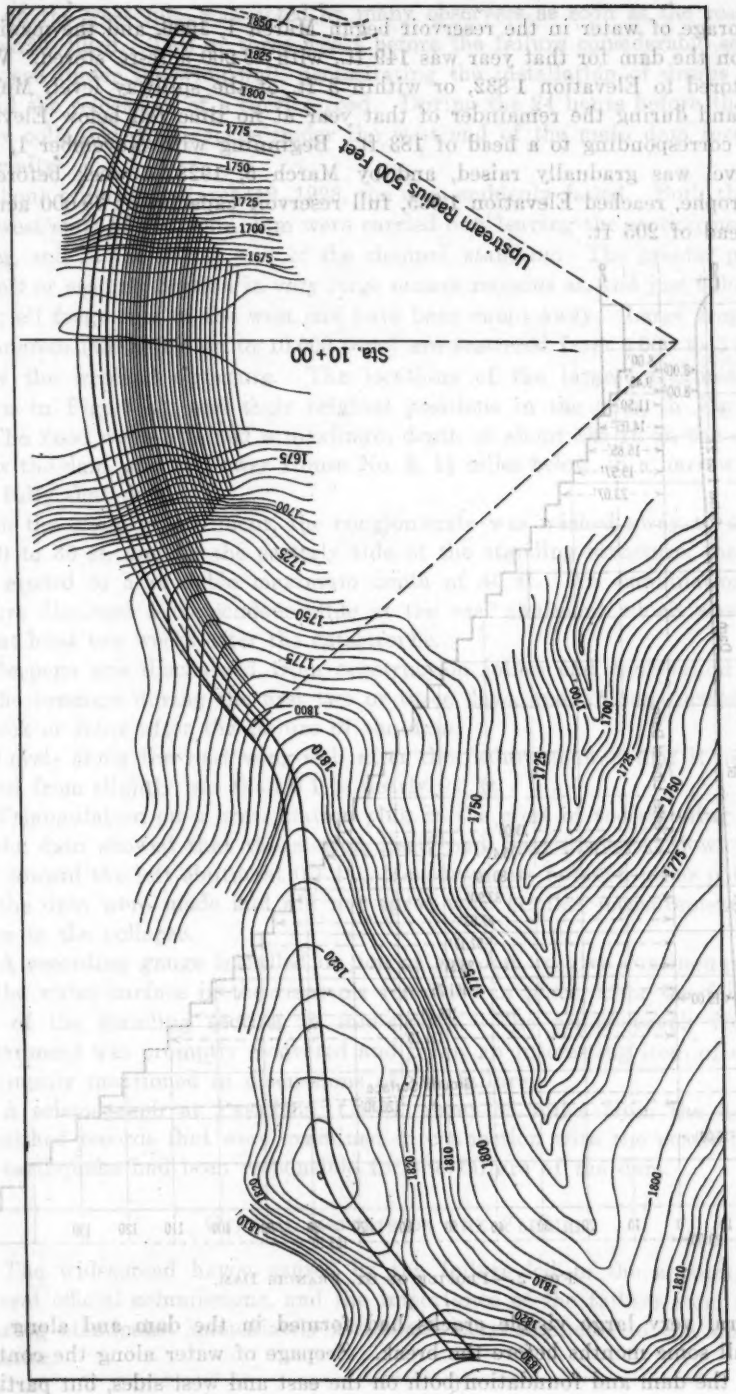

FIG. 1.—PLAN OF ST. FRANCIS DAM.

Storage of water in the reservoir began March 1, 1926, and the maximum head on the dam for that year was 149 ft., with 13 200 acre-ft. stored. Water was stored to Elevation 1 832, or within 3 ft. of the spillway level, May 10, 1927, and during the remainder of that year at no time fell below Elevation 1 813, corresponding to a head of 183 ft. Beginning with November 1, 1927, the level was gradually raised, and by March 5, 1928, a week before the catastrophe, reached Elevation 1 835, full reservoir capacity of 38 000 acre-ft., and head of 205 ft.

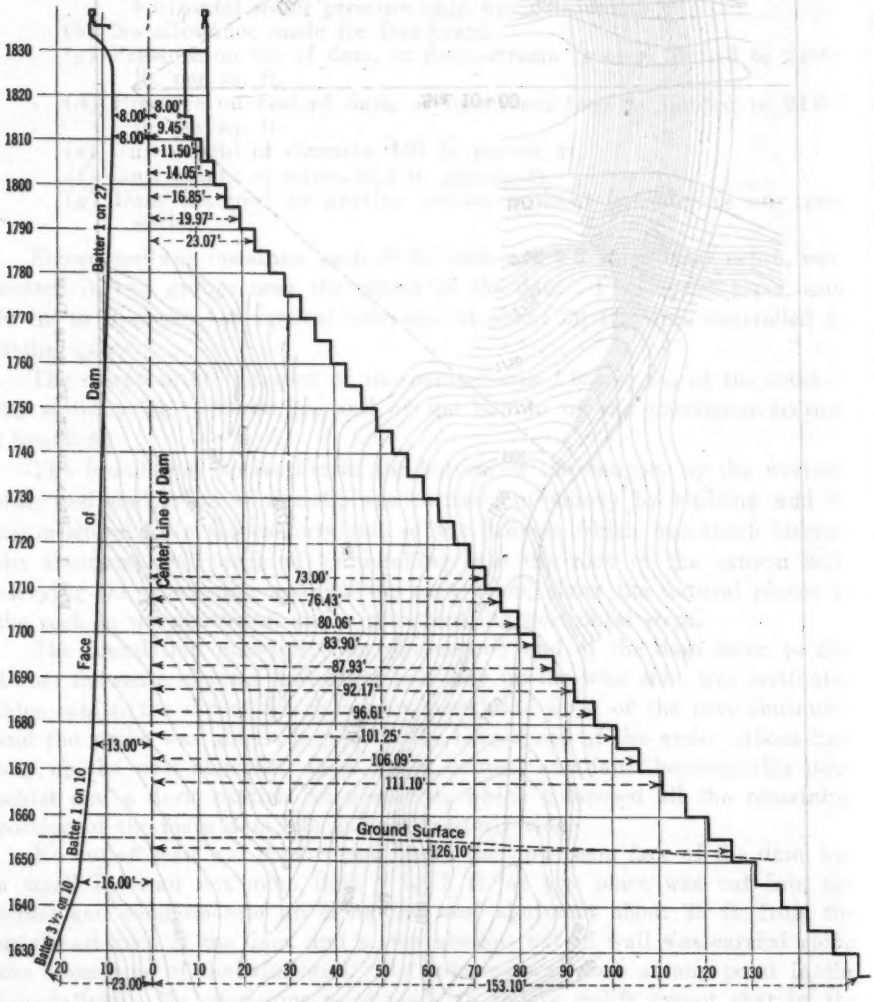

FIG. 2.—PROFILE OF ST. FRANCIS DAM.

Several very large visible cracks had formed in the dam and along the wing-wall some months before the break. Seepage of water along the contact between the dam and foundation both on the east and west sides, but particu-

larly on the west side, was noted by many observers as soon as the reservoir was partly filled. Two or three weeks before the failure considerable seepage developed under the wing-wall, necessitating the installation of drains below it, and the relocation of a service road. During the 24 hours before the dam finally collapsed, the seepage under the west end of the main dam increased materially.

About midnight, March 12, 1928, the dam suddenly failed. Both the east and west ends of the main dam were carried out, leaving the section near the center, and in the lowest part of the channel, standing. The greater part of the left or easterly portion in very large masses remains at, and just below, the dam; all fragments of the west end have been swept away. Large fragments of concrete (weighing up to 10 000 tons) are scattered from 2 000 to 3 000 ft. below the wrecked structure. The locations of the largest fragments are shown in Fig. 3(*a*), and their original positions in the dam, in Fig. 3(*b*).

The flood wave attained a maximum depth of about 125 ft. in the canyon below the dam, and at Power House No. 2, 1½ miles below, in a narrow gorge, was fully that depth.

In the westerly abutment, the conglomerate was washed away to a depth of 20 to 30 ft. and on the easterly side of the standing structure, the schist was eroded to a probable maximum depth of 40 ft. An examination after failure disclosed a tremendous slide at the east abutment which was active for at least two weeks after the catastrophe.

Seepage was discharged from construction joints and contraction cracks in the concrete during the first two or three days, and, in some cases, up to a week or more after the failure of the dam.

Levels along the west wing-wall after the failure showed that it had been raised from slightly less than 0.1 to nearly 0.3 ft.

Triangulation on a brass station plug in the crest of the standing section of the dam showed that the station itself had been displaced down stream and toward the left abutment 0.7 ft. Measurements between other points not on the dam were made and did not agree with similar measurements made prior to the collapse.

A recording gauge installed on top of the dam to give continouus record of the water surface in the reservoir remained in place, after the failure, on top of the standing section in mid-stream. The pencil graph from this instrument was promptly recovered and forms an interesting item of evidence frequently mentioned in discussions of the failure.

A seismograph at Pasadena, Calif., about 35 miles from the dam site, furnished records that were examined in connection with the possibility that an earthquake had been responsible for the failure of the dam.

Official Reports on the Failure

The widespread havoc caused by the failure led to the appointment of several official commissions, and the importance of the failure from an engineering standpoint immediately attracted many engineers to the site of the disaster.

The reports of the commissions were published in whole or in part in the technical press, which also contained a number of other very valuable articles by independent engineers.

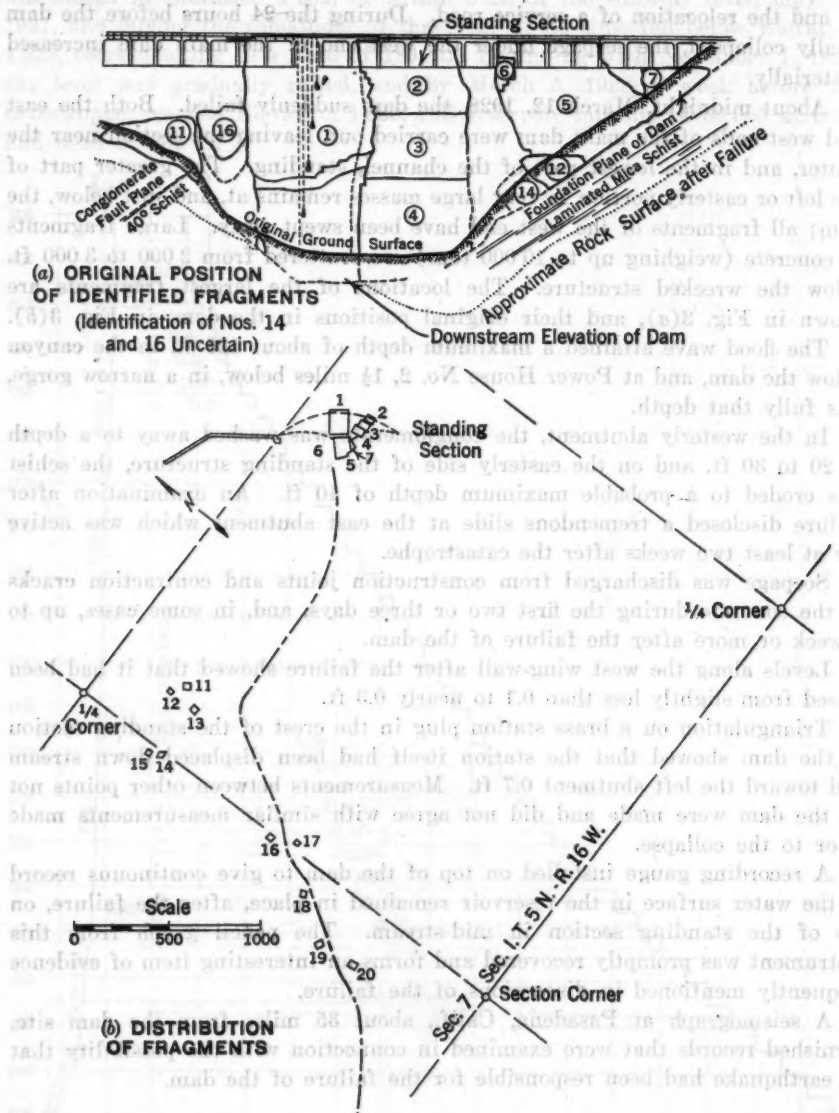

FIG. 3.—PLAN AND ELEVATION, ST. FRANCIS DAM, SHOWING DISTRIBUTION OF FRAGMENTS.

The Commissions were as follows:

1.—Committee appointed by the Board of Water and Power Commissioners of the City of Los Angeles.

2.—Committee appointed by District Attorney of Los Angeles County.

3.—The Commission appointed by the Governor of the State of California.
4.—The Committee appointed by the Los Angeles City Council.
5.—The Consultants selected by Santa Clara Water Conservancy District.
6.—The Jury drawn by the Coroner of Los Angeles County.

The findings of these various committees or commissions, and some comments as to the most important features of their reports are given herewith.

1.—Committee Appointed by the Board of Water and Power Commissioners of the City of Los Angeles.—On March 13, 1928, the Board of Water and Power Commissioners of the City of Los Angeles appointed a committee to examine the site and report upon the causes of the break. The Committee consisted of: D. W. Murphy, M. Am. Soc. C. E., Consulting Engineer; R. T. Hill, formerly Geologist, U. S. Geological Survey; and, C. F. Tolman, Professor of Geology at Stanford University.

On April 12, this Committee made its report which, however, was not printed for general distribution. The findings, which were concurred in by all the members, were as follows:

"(1) The manner in which the dam failed or where the first break occurred has not been determined. We feel that for us to attempt to answer these questions would be to indulge in opinion or speculation.

"(2) The failure was not due to inherent weakness in the cement structure.

"(3) There are no records of any seismic disturbances that could have caused the failure.

"(4) There were weaknesses in foundation under both the eastern (left) and western (right) abutments sufficient to have caused failure.

"(5) The weaknesses of the eastern abutment were due to existence and direction of the slope of the planes of schistosity. These planes, especially when wet, would permit easy sliding under the abutment.

"(6) The weaknesses on the west side were due to the inherent character of the foundation material.

"(7) The cementing material in the conglomerate consists of clay, which softens when wet and thus reduces the strength of the foundation material.

"(8) The conglomerate was cut by numerous fissures filled with gypsum. This gypsum is slowly soluble in water and any passage of water under the dam even in small amounts would in time produce openings. The dissolving and carrying out of the gypsum would produce a condition whereby the rock masses softened by water could be carried out of the foundation.

"(9) Recent surveys show small movement at two points on the right bank since the dam was constructed. It is possible that local movement of the conglomerate above the fault line may have been a contributing factor in starting the break."

In some general remarks, this Committee states that:

"It was clearly apparent early in our studies that the foundation rock upon which the dam stood was weaker and less able to support the load upon it than the material of the dam itself."

* * * * * *

"The weakness of the foundation on the eastern side is of a different character and less apparent than that of the western side. The schist layers lying parallel to the steep slope of the canyon are poised ready for sliding and any moistening of these slopes decreases the resistance of the rock against such motion. Any leakage occurring on the eastern side before the dam failed would wet the lamination planes and increase the tendency to slide."

2.—Committee Appointed by District Attorney of Los Angeles County.—About March 15, 1928, District Attorney Keyes appointed a committee of engineers and geologists to "investigate the disaster" made up as follows: E. L. Mayberry, Consulting Engineer; C. T. Leeds, M. Am. Soc. C. E., Consulting Engineer; W. G. Clark, M. Am. Soc. C. E., Consulting Engineer; A. E. Sedgwick, Professor of Geology, University of Southern California; and L. Z. Johnson, Geologist.

The findings of this Committee were presented to the Coroner's jury on April 3, but the report was not published.

The report of this Committee was unanimous. Some of the members supplemented the written report by appearing as witnesses and answering questions before the Coroner's jury. The main conclusions of the written report were, as follows:

"(1) The failure of the dam was due to defective foundation material, some of which, while reasonably hard when dry, became soft and yielding when saturated with water.

"(2) The defective foundation material referred to herein as conglomerate became softened by absorption and percolation of water from the reservoir and was by hydrostatic pressure pushed out from under the dam structure, permitting a current of water of high velocity to pass under this sector of the dam. This current, by eroding the soft foundation material quickly extended the opening under this portion of the structure to such an extent that a part of the Westerly sector of the dam collapsed through lack of support.

"(3) Following failure in the Westerly sector, the escaping water swirled across the down stream toe of the dam to the easterly side of the canyon, cutting away the Easterly wall of the canyon below the Easterly abutment, causing a slide which broke the already weakened bond between the Easterly sector and the side wall of the canyon, allowing the Easterly sector of the dam to collapse.

"(4) A portion of the Easterly sector of the dam fell and now lies upstream from the original face of this sector, indicating that this portion failed after the water level had dropped enough to materially relieve the pressure from the upstream face.

"(5) The top of the central sector of the dam now standing is approximately seven-tenths (0.7) of a foot downstream from its original position. The present angle of the upstream face indicates that in addition to moving downstream, this sector of the dam has rotated a slight degree, carrying the Westward side to the southeast.

"(6) Examination of the foundation material supporting the sector of the dam now standing, shows a fracture in the schist upon which this sector rests, indicating that the break which permitted the downstream movement, occurred in the foundation materials and not in the concrete of which the dam was constructed.

"(7) The condition of the foundation under the central sector and the foundation materials now attached to blocks of concrete carried downstream, indicate that the bond between the concrete and the foundation was stronger than the cohesion of the cleavage planes of the foundation materials.

"(8) The record made by the automatic recording gauge installed on the central sector of the dam, shows that for the period from midnight on March 11 to 11:30 P. M. on March 12, 1928, the water level in the reservoir dropped five hundredths (0.05) of a foot. The Bureau of Water Works and Supply reports that water was not drawn from the reservoir during this period. This

change in water level amounts to 1 335 114 cubic feet, which passed out of the reservoir during 23½ hours, or at the rate of 12.9 cubic feet per second. [Corrected for evaporation.]

"(9) The gauge record shows that the drop of water level in the reservoir from 8 P. M., March 12, to 11:30 P. M., March 12, was thirty-five thousandths (0.035) of a foot, or 934 580 cubic feet during 3½ hrs., or at the rate of 74 cubic feet per second.

"(10) The gauge indicates that the collapse of the dam occurred between 11:30 and 11:50 P. M. The movement of the gauge after 11:30 is so rapid that it can not be accepted as an indication of the water level in the lake, but merely as an indication of the water level at the face of the dam.

"(11) It is the conclusion of this Board that the dam was constructed without a sufficiently thorough examination and understanding of the foundation materials upon which the dam was constructed.

"(12) It is the conclusion of this Board that failure of the dam was due to the incompetent geological formations upon which the dam was constructed.

"(13) It is the conclusion of this Board that the dam as designed should not have been constructed at this location.

"(14) It is the conclusion of this Board that due to local conditions it is not economically feasible to erect a safe dam at this location."

In some general remarks, this Committee states that it has found no evidence to support a theory that the failure might have been caused by either an earthquake or an explosion. It makes the recommendation that a State Board should be constituted to pass upon the design, foundation conditions, and construction of all dams in the State.

3.—The Commission Appointed by the Governor.—On March 17, 1928, Governor Young announced the selection of four engineers (two geologists being afterward added) to "investigate the causes leading to the failure." The personnel of this commission was as follows: A. J. Wiley, M. Am. Soc. C. E., Consulting Engineer; F. E. Bonner, M. Am. Soc. C. E., District Engineer, U. S. Forest Service; F. H. Fowler, M. Am. Soc. C. E., Consulting Engineer; H. T. Cory, M. Am. Soc. C. E., Consulting Engineer; G. D. Louderback, Professor of Geology, University of California; and F. L. Ransome, Professor of Geology, California Institute of Technology.

The complete report, published by the California State Printing Office, forms a pamphlet of 79 pages illustrated by 20 plates. Two illustrations are included herewith (see Figs. 4 and 5). This Commission reported its unanimous conclusions on March 27. These were:

"(1) The failure of St. Francis Dam was due to defective foundations.

"(2) There is nothing in the failure of the St. Francis Dam to indicate that the accepted theory of gravity dam design is in error or that there is any question about the safety of concrete dams designed in accordance with that theory when built upon even ordinarily sound bed rock. On the contrary, the action of the middle section which remains standing, even under such adverse conditions, is most convincing evidence of the stability of such structures when built upon firm and durable bed rock.

"(3) The failure of this dam indicates the desirability of having all such structures erected and maintained under the supervision and control of state authorities. Water storage, with its necessary concomitant dams and embankments, is peculiarly essential to the development of California resources, and in the great majority of cases failures would result in serious loss of life and property. This disaster emphasizes the fact that while the benefits accrue to

the builders of such projects, the failures bring disaster to others who have no control over the design, construction and maintenance of the works. The police power of the state certainly ought to be extended to cover all structures impounding any considerable quantities of water."

In support of the conclusions the report states, in part, as follows:

"The first indication of failure, given by the automatic water register located on top of the central or standing section of the dam, was a gradually accelerated falling of the water surface, starting about 11:30 P. M. (corrected time) and aggregating about three-tenths (0.3) of a foot at about 12 P. M., when the failure was indicated on the record by a rapid fall in the water surface."

* * * * * *

"The material in the dam is demonstrated by inspection, by tests, and finally by behavior of enormous blocks remaining from the wreck, to have been of satisfactory quality and adequate strength. Tests of samples cut from typical blocks showed an average crushing strength of about 2 400 pounds per square inch, which is much beyond any stresses to which it could have been subjected under normal conditions.

"There were no contraction joints built in the dam, which is the case in many existing dams, and, in any event, the failure can not be attributed to their absence.

"There can be no question but that such a dam properly built upon a firm and unyielding foundation would be safe and permanent under all conceivable conditions, except perhaps faulting and earthquake shocks of tremendous violence. Indeed such a dam may properly be deemed to be among the most durable of all man-made structures. Unfortunately in this case the foundation under the entire dam left very much to be desired. The material under the central and left, or easterly, end was a mica schist of thin and easily separable laminæ. The west end was founded upon a reddish conglomerate which, even when dry, was of decidedly inferior strength and which, when wet became so soft that most of it lost almost all rock characteristics. Numerous samples taken from the present surface which has been eroded to a considerable depth below the original foundation and some samples from underneath the remaining west wing wall, quickly softened and changed into either a mushy or granular mass when immersed in water. Unfortunately this material is of such a nature that when entirely dry it is hard and rock-like in appearance and characteristics, although defective in compressive strength. Of two samples taken from the firmest part of the eroded foundation, one broke in preparation for testing and the other, cut into a 5.77 inch cylinder 7.12 inches long, showed a compressive strength of only 523 pounds per square inch, or between one-fourth and one-fifth that of the concrete in the dam. Greater strength might have been shown had the sample not been moistened by exposure at the time of the dam failure, but on the other hand it would have been much weaker with a larger moisture content.

"With such a formation, the ultimate failure of this dam was inevitable, unless water could have been kept from reaching the foundation. Inspection galleries, pressure grouting, drainage wells and deep cut-off walls are commonly used to prevent or remove percolation, but it is improbable that any or all of these devices would have been adequately effective, though they would have ameliorated the conditions and postponed the final failure."

* * * * * *

"Many of the available data indicate that the initial foundation failure occurred near or at the old fault or contact between the conglomerate and schist under the west end, and was due to the percolation of water into and through this section of the foundation, with resulting softening of the con-

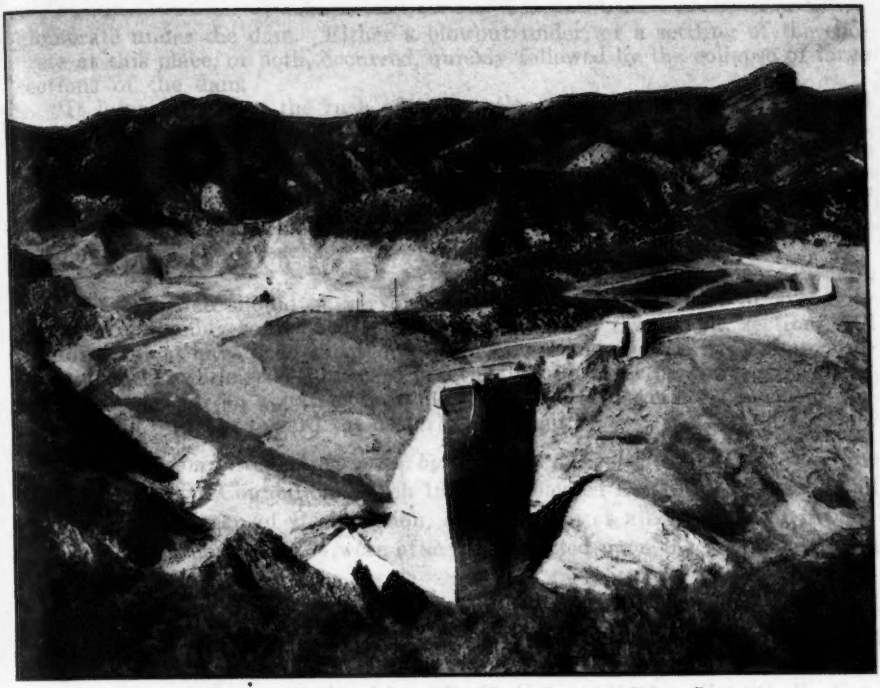

FIG. 4.—VIEW OF SITE OF ST. FRANCIS DAM, LOOKING DOWN STREAM.

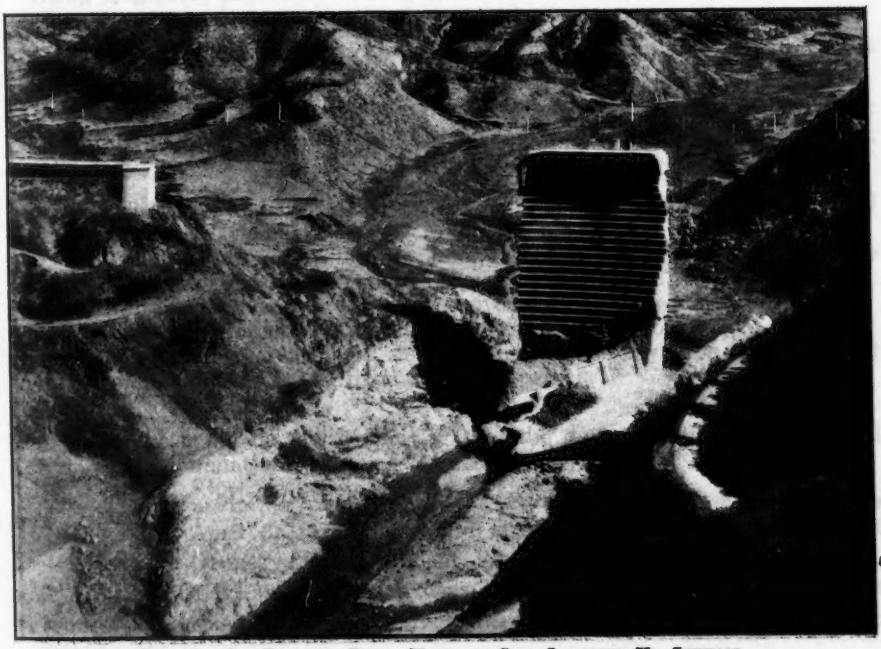

FIG. 5.—ST. FRANCIS DAM: VIEW OF SITE LOOKING UP STREAM.

glomerate under the dam. Either a blowout under, or a settling of the concrete at this place, or both, occurred, quickly followed by the collapse of large sections of the dam.

"It is probable that the rush of water released by failure of the west end caused a heavy scour against the easterly canyon wall at the toe of the dam. This rapidly cut away the schist including the material under the toe of the east part of the dam and caused the failure of that part of the structure. The escaping water then continued to cut away the schist from the east wall of the canyon until a maximum depth of about 30 feet below the original foundation level was reached."

* * * * * *

"A fact which should be very reassuring as to the stability of a gravity dam on reasonably sound bed rock is that although the central section, still standing, must have been exposed to tremendous and sudden stresses amounting to shocks, while still subject to practically full water pressure, it is undisturbed except for an apparent movement at the top of some 5.5 inches downstream and 6 inches toward the easterly abutment."

4.—The Committee Appointed by the Los Angeles City Council.—The Los Angeles City Council on March 16, 1928, selected Dr. Elwood Mead, Chief of the U. S. Bureau of Reclamation, as Chairman of a committee of investigation. The other members were afterward selected upon the recommendation of Dr. Mead.

This Committee was constituted as follows: Elwood Mead, M. Am. Soc. C. E., U. S. Reclamation Service; L. C. Hill, M. Am. Soc. C. E., Consulting Engineer; and, Lansing H. Beach, M. Am. Soc. C. E., Consulting Engineer.

The Committee was assisted by: D. C. Henny, M. Am. Soc. C. E., Consulting Engineer; and R. F. Walter, M. Am. Soc. C. E., Chief Engineer U. S. Reclamation Service.

Its report was filed with the City Council and was published in full, except for some exhibits.*

The Committee agreed with the other investigating bodies in attributing the failure to faulty foundation, as shown in the following quotations from its report:

"(1) The type and dimension of the dam were amply sufficient if based on suitable foundation.

"(2) The concrete of which the dam was built was of ample strength to resist the stresses to which it would normally be subjected.

"(3) The failure cannot be laid to movements of the earth's crust.

"(4) The dam failed as a result of defective foundations.

"(5) This failure reflects in no way on the stability of a well designed gravity dam, properly founded on suitable bedrock."

* * * * * *

"It is the belief of this committee that the dam failed because it rested on defective foundation."

5.—The Consultants Selected by the Santa Clara Water Conservancy District.—On April 3, 1928, the Santa Clara Water Conservancy District selected C. E. Grunsky, Past-President, Am. Soc. C. E., and E. L. Grunsky, M. Am. Soc. C. E., as engineering consultants and authorized them to select a consulting geologist. Dr. Bailey Willis, Professor Emeritus, of Stanford

* *New Reclamation Era*, Vol. 19, pp. 66–71.

University, was chosen, and reported on April 10, 1928. The combined engineering and geological report was submitted April 19, 1928, and has been printed in full.*

The conclusions of the Engineering Report are as follows:

"1. The site at which the dam was built is not a suitable site for a dam of the type which was there erected.

"A solid gravity section dam, without thorough hillside and foundation drainage is adapted only to locations where contact of the masonry with the bedrock material, preferably fortified with deep cut-off walls along or near the up-stream face, either completely intercepts the flow of water under the dam or checks it to such an extent near the up-stream face that only moderate hydrostatic pressure can develop under the dam. Where sites are suitable, cut-off walls and foundation and hillside drainage down-stream therefrom accomplish the desired result.

"2. Neither solid gravity dams nor other types of dams which are rigid should be selected for localities where minor earth movements such as slides or swelling ground are probable.

"The old slide against which the dam rested at the east, its composition of mica schist bedded at an angle of, or approaching 45° with the horizontal, practically paralleling the general slope of the canyon wall, and shattered by previous movement, subject to lubrication with water from the reservoir as well as with infiltering rainwater, offered only insecure support to the dam, and this was rendered more precarious by the adoption of a design which did not include adequate foundation drainage.

"At the west end of the dam, the material on which it rested is more or less pervious and softens when wet. It remains doubtful whether any precautions (such as cut-off walls and weep-holes) could have made this a satisfactory foundation.

"3. The appearance, as early as January, 1928, of cracks in the dam other than temperature cracks, indicated a movement of the dam. Apparently the significance of these cracks was overlooked. A thorough study of the situation at that time should have disclosed most of the facts now known as to the unfavorable features of the damsite.

"4. The failure of the St. Francis Dam was due to unsuitability of the foundation for the type of dam there built."

The conclusion in the Geological Report is as follows:

"I conclude that the dam failed as it did because the character of the east abutment was overlooked.

"It failed when it did because the water had by that time saturated the east abutment to the degree necessary to free the down-stream portion of the slide in front of the fault.

"I think the dam would have failed at some later time in consequence of the softening of the rock in the long ridge west of the main structure, even if the east abutment had held."

Preceding these conclusions is the following detailed statement concerning the failure of the dam:

"The study of the geologic conditions leads to the following explanation of the failure. It would seem that the events succeeded in the following order:

"(*a*) Both abutments became saturated with water, but the critical situation developed more rapidly in the east abutment.

"(*b*) The water reached one or more fault planes back of the lower part of the east abutment, and it slid out by reason of its own weight.

* *Western Construction News*, Vol. 3, pp. 314–320 and 409–413.

"(*c*) The upstream portion of the east abutment was left unsupported by the removal of the lower part and was swept out by the first advance of the water under full head.

"(*d*) The east wing of the dam was left in the air and its weight tilted the whole concrete structure toward the east, as is shown by the ladder that was washed into the crack at the western base of the central monolith and is now pinched in it.

"(*e*) The west abutment was swept out by the water rushing under the left wing as it was raised by the tilting.

"(*f*) The east wing was broken off by the resultant of its own weight and the pressure of the current acting with the leverage of its center of gravity from the line of fracture. The tension previously set up in the arch by the thrust of the abutment may have helped to orient the vertical line of fracture.

"(*g*) The dam tilted back westward under the pull of the west wing, and the latter broke off under stresses similar to those that had broken off the east wing. The two wings must have gone in quick succession, but the volume of water flowing past the eastern side of the central monolith was better maintained because the deep straight side of the channel in the reservoir lies on that side.

"(*h*) The central monolith was rocked forward as the wings resisted the current and the pressure broke off the toe of the dam; but when the wings gave way the monolith righted itself, apparently without having turned on its base."

6.—The Jury Drawn by the Coroner of Los Angeles County.—The disaster involved the loss of many human lives and the Coroner of the County of Los Angeles impaneled the following jury to consider the testimony to be presented: O. G. Bowen, M. Am. Soc. C. E., Contractor; W. H. Eaton, Jr., Contractor; I. C. Harris, Associate A. I. E. E., Construction Engineer; H. G. Holabird, Real Estate; S. C. Lines, Broker; Z. N. Nelson, Construction Engineer; Blaine Noice, Assoc. M. Am. Soc. C. E., Structural Engineer; C. D. Walz, Mechanical Engineer; and, Ralph F. Ware, Affiliate, Am. Soc. C. E., Insurance.

This jury examined many witnesses including the engineers who had comprised the Committee appointed by the District Attorney of Los Angeles County. It also examined the site of the broken dam, and after investigating the whole matter for about three weeks, it filed its verdict on April 12, 1928. The jury concluded that:

"The St. Francis Dam was defective due to the very poor quality of the underlying rock structure upon which it was built and to the fact that the design of the dam was not suited to inferior foundation conditions. The actual failure was caused either wholly or in part by these defects.

"The construction of this dam, without having the design and foundation conditions passed upon by independent engineers and geologists, and without more thorough and systematic methods of design, supervision and inspection, involved two basic errors.

"One of these was an error in engineering judgment in determining the character of the foundations at the St. Francis Dam site and deciding upon the best type of dam to build there.

"The other was an error in regard to fundamental policy relating to public safety.

"The responsibility for the error in engineering judgment rests upon the Bureau of Water Works and Supply, and the Chief Engineer thereof.

"The responsibility for the error in public policy belongs to those to whom the Chief Engineer is subservient, including the Department of Water and Power Commissioners, the legislative bodies of city and state, and to the public at large. It is a logical result of a set of conditions that the citizenship has allowed to develop and continue. This is the more fundamental error, for if proper safeguards had been provided in the city charter and in the state laws, making it impossible for excessive responsibility to be delegated to or assumed by any one individual in matters involving great menaces to public safety, it is unlikely that the engineering error would have escaped detection and produced a great disaster.

"A sound policy of public safety and business and engineering judgment demands that the construction and operation of a great dam should never be left to the sole judgment of one man, no matter how eminent, without check by independent expert aythority,* for no one is free from error, and checking by independent experts will eliminate the effect of human error and insure safety.

"The exemption of municipalities from supervision by state authorities in the building of dams involving public hazards is a very serious defect of the state law that should be corrected.

"The dam was built without predetermined expansion joints. This is a debatable question; but the best practice at present calls for their use.

"The St. Francis Dam was built by the Department of Water Works and Supply of the City of Los Angeles, by the City's own forces and not by contract.

"The design of the dam and the foundation conditions were not passed upon by independent engineers and geologists.

"The exploration work and testing of foundation materials prior to reaching a decision to build a dam at this site, were entirely inadequate to definitely determine the true qualities of the bedrock and the proper type of dam to build at the site.

"Among the possible causes of failure that have been considered is that of earth movement. Triangulation surveys have been made that seem to indicate that there has been a slight movement of two survey points on the West side of the site between the year 1923 and a time three weeks after the failure, but it is impossible to check the original survey. Seismographs were in service in several observatories within range of this site, one of them being within 45 miles. The records show that there were no earth tremors of even slight intensity on the night of the failure; hence, major earth movement must be dismissed as a possible cause.

"Landslides on the east side of the canyon accompanied the destruction of the dam. Whether a landslide was the first event or only a later development is a subject concerning which there may be a difference of opinion, or at least, an uncertainty, but the preponderance of expert opinion favors the conclusion that the initial failure was on the west side and that the landslides were precipitated by undercutting by the waters discharged through the breach on the west end of the dam. Some of the slides are known to have occurred after the water had left the reservoir.

"The exact sequence of these events is of great engineering interest but has little bearing on the question of basic cause and responsibility. A susceptibility to landslide was one of the defects of the site that should have been foreseen."

No criminal responsibility was found and no criminal prosecutions were recommended.

* Error in original report.

Closure

The Committee of the Board of Direction observes that there is only one outstanding difference of opinion among the various official committees, *viz*, as to the location of the point of beginning of the break up. Some of the reports express the belief that the break-up started at the west abutment, others at the east, and others reach no conclusion on this point.

All official committees agree that:

(1) The dam failed because of weaknesses inherent in the foundations.

(2) The concrete of the dam was of satisfactory strength. Four of the reports agree that earthquakes were not responsible for the failure.

Some of the reports affirm a confidence in the "gravity dam" built on proper foundation, and some recommend State supervision over the design and construction of dams. It will be noted that the State of California has subsequently enacted legislation with this intent.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

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GENERAL CONTRACT SYSTEM VERSUS SEGREGATED CONTRACTS

Discussion*

BY WARD P. CHRISTIE, ASSOC. M. AM. SOC. C. E.†

WARD P. CHRISTIE,‡ ASSOC. M. AM. SOC. C. E. (by letter).§—This paper,‖ which set forth the advantages of the general contract to owners, has developed many interesting and valuable observations. The writer feels indebted to all those who took part in the discussion for having contributed their time and constructive thought to this rather spiceless subject. He would like to respond to the courtesy of discussion by acknowledging each individual observation, but that is not feasible.

Some of the discussion indicates that the paper was interpreted to raise an issue between contractors and professional engineers with respect to the two systems of contracting, but this was not its intent. Such issues as do exist were not assumed to involve the professional man as one party, but to rest principally between two groups of commercial organizations. It is not clear to the writer how a professional engineer can be a fixed proponent of one contracting system on all occasions, unless he ceases to remain professional, or begins to commercialize his profession.

In several parts of the discussion resentment cropped out against any thought that engineering ability, *per se*, does not qualify one to manage construction; and this thought might profitably be developed, but there are so many current conceptions of engineering, that the subject becomes hopelessly confused. It appears advisable, therefore, to eliminate this point as far as possible in comparing the two contract systems. This may be done by assuming that any competent engineer is capable of performing the services of a responsible general contractor.

* Discussion of the paper by Ward P. Christie, M. Am. Soc. C. E., continued from August, 1928, *Proceedings*.

† Author's closure.

‡ Engr., The Associated Gen. Contrs. of America, Inc., Washington, D. C.

§ Received by the Secretary, August 12, 1929.

‖ *Proceedings*, Am. Soc. C. E., February, 1928, Papers and Discussions, p. 395

Since it is not practicable to deal with all the views expressed, the writer's closing discussion is confined to five points which appear to be in need of emphasis or further clarification. They are as follows: (1) Judicious Selection of a System; (2) Engineering Service; (3) Construction Service; (4) Liability of Owners; and (5) Ethical Considerations.

Judicious Selection of a System.—In view of the conflict of thought which usually attends a discussion of contracting methods, the clear observations of Professor Lyle* are pleasing. He makes the point that construction projects vary in character from those that are obviously suitable for one system to those that are obviously suitable for the other, and that in between these extremes are projects which necessitate, in the selection, an individual exercise of judgment.

An example of a project clearly requiring the general contract is the subway job mentioned by Mr. Ridgway.† Its many different parts are so closely interlocked and its management so specialized that segregation into separate contracts would place an enormous risk upon the public body. Probably each contractor would be obliged to include a heavy contingent allowance in his bid to cover the hazard of poor co-ordination.

An example of the other extreme involving little hazard to an owner, is a steel bridge, such as that mentioned by Mr. Ballard,‡ for which the work is physically separated into various parts, which are not built simultaneously. On a project such as this no great degree of co-ordinating management is necessary. Each contractor could work without interference from others, and such interlocking as occurred between abutments, superstructure, and roadway surfacing, could be handled without placing material risk upon an owner.

It should not be inferred from these examples which illustrate only the feature of risk to an owner, that a general contract is unsuitable to projects that lack the characteristic of interlocking. Numerous other factors are involved in a judicious selection, and they can only be judged by considering the circumstances which attend the specific project. Some of these factors are as follows:

(*a*) Magnitude of the entire project and its component parts.
(*b*) Availability of equipment and duplication of contractor's outfits.
(*c*) Competitive conditions in the general and specialized contracting fields.
(*d*) Sources of labor and duplication of labor camps.
(*e*) Necessity for speed.
(*f*) Relative prices as shown by actual bids.

If a contract system were selected according to a judicious weighing of these factors, probably the issue between general and separate contracts would disappear. The issue does not usually arise from disagreement as to the need for co-ordinating management, but from disagreement as to who should perform that service.

Some engineers desire to perform it because they believe they can manage the job and save money for client or employer; some have had unsatisfactory

* *Proceedings*, Am. Soc. C. E., April, 1928, Papers and Discussions, p. 1321.
† *Loc. cit.*, August, 1928, Papers and Discussions, p. 1923.
‡ *Loc. cit.*, p. 1927.

service from general contractors; others are disgusted with the way that some contractors treat their sub-contractors; but in a great many cases separate contracts are used because of self-interest of the agency that has the decision. Some one is interested in expanding or solidifying his job, gaining experience to enter business, or performing the general management for a commission.

If the paper did reflect the categorical "no" for separate contracts, to which Professor Lyle objected,* it was an unconscious reaction to the categorical "yes" of many who sell their services or hold their positions through that system. His advice against becoming proponents of either system, sound as it is, will conflict with the self-interest of this class. They are undergoing or have completed the transition from profession to business.

Individuals or firms that desire to engage in the business of construction management, without entering the field as contractors, must become proponents of the separate contract system. Their services are as inherently linked with that system, as a general contractor's are linked with the other. Therefore, except in those cases where decision is in the hands of a professional engineer, who is not desirous of managing construction for financial gain or experience, judicious selection of a system with respect to the clients' or employers' interest is not likely to be the rule. It is too closely linked with the question of profit, commission, or salary.

Engineering Service.—A number of observations made in the paper were based on the assumption that those who call themselves engineers are engaged in the practice of a profession. Otherwise, the discussion becomes irrational. If it is actually desired to clarify the separate-contracts issue, rather than confuse it, a distinction must be made between professional engineering and the many business activities that have borrowed its name.

According to Webster a profession is "a calling in which one professes to have acquired some special knowledge used by way either of instructing, guiding, or advising others, or of serving them in some art". This is a definition that seems to fit the men who, in former years, were called engineers. Those who design construction projects and who supervise their building are undoubtedly doing professional work, if the purpose of supervision is to see that a client obtains what he bought. They have no personal interest in recommending a specific material or system of contracts and are not in such a position that their advice to a client or employer could be influenced by any possibility of their financial gain or loss. These appear to be the basic characteristics of a profession.

When this conception of professional engineering is compared with Mr. Dougherty's definition† of an engineer, it would seem that the two bear very little relation to each other. The latter does not appear to describe those men who are the backbone of the Engineering Profession. It fits more closely those who have left the practice and have entered into business.

During the last decade many men who were engaged in the profession of engineering have developed themselves along the line of construction man-

* *Proceedings*, Am. Soc. C. E., April, 1928, Papers and Discussions, p. 1322

† *Loc. cit.*, May, 1928, Papers and Discussions, p. 1632.

agement. They are operating either as contractors, in the generally accepted sense, or as construction managers, under the appellation of engineers. Some who are strictly business executives and completely out of touch with matters of the profession, still cling to their earlier title and inflate the definition of an engineer to fit their later accomplishments. Apparently, the title of engineer is a garment of respectability which one is reluctant to lay aside when he emerges from the profession into the supposedly less respectable field of business.

Such juggling of terms, however, should not obscure the fact that engineering as understood by most of the world is a profession, which requires its particular type of mind and ability. It is a most honorable and useful vocation, but proficiency in engineering does not of itself equip one for construction management.

The fact that some individuals pass from engineering into business and succeed, should not delude engineers as a class into thinking that every competent member of the profession can do likewise. The field of construction management and that of engineering are vastly far apart, and few individuals are able to master both. The professional engineer therefore should move cautiously when he decides to experiment with separate contracts. He may well pause and consider whether it is ethical for him to acquire his business experience at the risk of some one else, for he is risking his client's or employer's money and not his own.

Construction Service.—Two principal types of construction service are furnished by firms calling themselves either engineers or contractors. One is based on the separate contract system and the other on the general contract. Either may include both design and construction, but this has no particular bearing on the nature of the construction function itself. The one based on separate contracts does not include collectible guaranties, but it protects an owner's interests to the extent of the skill and integrity of the constructing firm. The one based on a general contract gives not only the protection of skill and integrity, but also that of financial responsibility. It includes guaranties covering time of completion, claims, and cost of the project as a completed whole.

Performance of either of these services in a proper manner is an honorable vocation, but one should not be recommended to a client or employer when the other will serve his interests better. If an owner has a definite limit to the amount he may invest in construction, and cannot afford to take a chance on an over-run of cost or damages, he should obviously have a service that will absorb the risk of such occurrences. This can be practically provided only by the use of a general contract. On the other hand, if the owner is not limited to a definite expenditure, and is willing to assume the risk of management, then the separate system fits his needs.

At present, separate contracts service is extensively identified with firms called engineers and the general contract with firms called contractors, although on occasion either one or both services may be supplied by the same company. The firms themselves are practically alike, except that some of the directing

heads were once engineers, while others grew up in the ranks of business. Irrespective of what they call themselves, the successful ones are headed by competent business executives, and not by professional engineers.

Some of these firms offer various types of super-construction service, dressing them up as professional services; but one is only fooling himself if he thinks that construction management is not a business; and he is certainly fooling his client if he represents it as a profession.

The unvarnished fact is that these super-services are composed of two elements: One is design, furnished by professional men; and the other is construction management, performed by business executives. The fact that designers and managers are associated in one firm does not alter the kind or amount of service necessary for a construction project. It does not eliminate either the fee for design or the fee for management. These fees are merely combined as one and paid to a single concern.

The really significant feature of the super-service is that both the mistakes of engineering, and the shortcomings of management "come home to roost on the same perch". When the job does not progress properly, the firm that combines both design and construction has no one to whom it can "pass the buck". This may be a great advantage to an owner, if he is using a general contract, as any loss from mismanagement will then fall on the constructor; but if he is using separate contracts, the super-service avails him nothing. The managing agency does not assume any over-run of expense and the loss will fall on the owner.

The significance of these circumstances is readily perceived when one learns what has been decided about the owners' responsibility by the Courts.

Liability of Owners.—Legal aspects of the two contracting systems were treated briefly in the paper;* but there was practically no discussion of this subject and it is of most vital concern to owners. The fact does not seem to be generally known that various warranties, which do not concern public or private owners under a general contract, are placed upon them when the work is divided among independent contractors.

On certain types of projects, on which one contractor is sure to complete his work and be out of the way before another is due to begin, this responsibility may be of little consequence, but on other types it becomes a serious matter. If the work of the various contractors must proceed simultaneously, or if the progress of one depends upon the performance of another, the owner has a legal responsibility for synchronizing and co-ordinating their operations. It is his duty, exercised of course through an agent, to see that no one of the independent contractors injures the work or impedes the progress of another. These conditions are implied toward all and the Courts have held him accountable.

Naturally if the managing agency is capable and experienced, it can greatly minimize the risk, but no amount of skill or experience can insure that valid damage claims will not arise. Such insurance can be given only by some agency that is financially able and willing to absorb the loss.

* *Proceedings*, Am. Soc. C. E., February, 1928, Papers and Discussions, p. 399.

A very clear example of how claims originate merely through interference of one contractor with another is found in the case of the Edge Moor Iron Company *vs.* United States.* The Iron Company had a contract for furnishing and installing certain boilers upon foundations which were being built for the Navy Department by another contractor. Each had a separate contract with the Government. The work was not complicated and there was not much interlocking with respect to time or position; in fact, the project was one requiring a minimum of co-ordination.

The foundations were not completed according to a schedule such that the Iron Company could carry out its work in a manner inferable from its contract, and it was subjected to considerable delay. This delay, which increased the contractor's expense, constituted a breach of contract on the part of the Government, thereby establishing valid grounds for claim. Mere extension of contract time did not compensate for the delay.

In rendering a decision, the Court of Claims pointed out that, although the foundations were not built by Government forces, the Government could not escape liability. It had breached a condition necessarily implied by the separate contracts, that it would co-ordinate the work of all contractors so that each might perform his part as indicated by his contract.

The Edge Moor decision and other similar ones rendered by the U. S. Supreme Court and the Court of Claims demonstrate that separate contracts contain a serious loophole for claims. If any one of the contractors is of the kind that makes his profit out of suing on technicalities, he can cause trouble on almost any job of interlocking parts. When a suit does occur, the owner's only hope of avoiding loss is that of suing his own agent or a delinquent contractor. Possibly the delinquent contractor may have been unavoidably delayed.

In such cases the contractor's defense is very often made secure by some complication of circumstances or by technicalities which involve the engineer. It is not unprecedented for a number of suits to grow out of a single job. Such occurrences would probably be more frequent were it not for the fact that a responsible contractor ordinarily would rather take a loss than go to Court.

There is no practical way to eliminate the hazards of these circumstances through the wording of contracts. It has been tried repeatedly without success. If the provisions are made "tight" enough to block claims that might arise from separation of the work, they are so "tight" that responsible contractors often decline to bid. If they do bid, they must include in their prices an extra allowance for contingencies.

This situation is partly responsible for the development of the general contract. It serves as a sort of contingency trap to catch all the overcharge, short, and damage claims arising from the complexity of the work. Under this contract any judgments obtained by the specialized contractors or others must be satisfied by the general contractor or his surety. They are hazards under the system.

* 61 Ct. Cls. 392.

Ethical Considerations.—The paper was characterized by Mr. Muhs* as a plaint that "engineers, by a system of segregating contracts, are usurping the functions and encroaching upon the field of the general contractor". This is a surprising reaction, because such plaint as may have been readable between the lines was not for general contractors. It was for those many men who respect and practice the profession of engineering.

General contractors are not fearful that the need for their services will be eliminated by separate contracts. A few more outstanding failures on public buildings, on which inexperienced men are experimenting with this system, will kill it in the public field. If it should become predominant in private work, contractors will merely adopt the system. If necessary they will associate professional engineers with their organizations, and render both design and construction service. There is nothing mysterious about it that gives a monopoly to management agencies called engineers.

What causes contractors to condemn separate contracts is not a loss of business, or even the nature of the system itself; but the misstatements or ignorance by which owners or employers are frequently induced to use the system. Owners are commonly told that separate contracts provide them with a service as complete and as fully protective as that of the general contract; and that they can eliminate the services of a general contractor and save the expense of his service. Such statements are subtle and dangerous misrepresentations, which many owners are unable to detect.

When an owner is willing to assume the risk entailed by separate contracts and accepts the proposition with full knowledge of their character, no one can have any just complaint about their use. It is a matter of concern only to those directly concerned in the transaction. However, if the owner is induced to use the separate system through statements that it places no more risk and responsibility upon him than does the general contract; or, if an engineer, with no experience in construction management, represents himself as competent to replace an experienced contractor, then a question of ethics is clearly involved.

Such practices are misrepresentations of kind and quality that fall into the same category as the misbranding of commercial products. They are no more related to honorable business than are the actions of some contractors that skimp their work or undertake projects which they know they cannot perform.

For a number of years complaint against the methods used in promoting separate contracts has been growing, but since the profession has taken no great interest in the matter, and since many contractors had hands that were anything but clean, the subject has had very little frank discussion. It is no longer a matter of concern only to the owner and his engineer. It concerns both the business of contracting and the profession of engineering. From the discussion, it is evident that the basic need for analysis is not on the theory of the systems, but on ethical practice for their use. It is not beyond the possibility that the profession is losing its prestige through the aspirations of members toward business, and through the practices of some who have already made the transition.

* *Proceedings*, Am. Soc. C. E., May, 1928, Papers and Discussions, p. 1626.

To any one who may imagine that the paper was merely a plaint of contractors, or that there is no real question of ethics involved in the use of separate contracts, the writer commends a reading of Section 2, Part III, of the Society's Code of Practice.* It is as follows:

"The Engineer shall call the owner's attention to the fact that under a general contract for a project the Contractor assumes large responsibilities for organization, co-ordination, and management which, under segregated contracts, must be borne by the Owner or Engineer. Further, that in many cases a general contractor, with control of and responsibility for these phases of organization, co-ordination, and management, may secure economies of costs and time in the benefits of which the Owner will share."

* Manual of Engineering Practice, No. 1, Am. Soc. C. E.

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PAPERS AND DISCUSSIONS

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EFFECT OF EARTH SHOCKS ON STRUCTURES

Discussion*

By M. de Bussy, Esq.†

M. de Bussy,‡ Esq. (by letter).§—The conclusions of Dr. Briske,‖ referring mostly to the so-called "forced oscillations", are based necessarily on the assumption that the oscillating motion of the ground remains constant for a definite but unknown length of time. The shocks that occur in a destructive earthquake rarely seem to be of such a nature. This fact has been clearly shown¶ by H. D. Dewell, M. Am. Soc. C. E. Moreover, witnesses generally report the greatest destruction of buildings during the very first shocks. The writer believes, therefore, that it is fully as important to investigate the stresses in a structure at the beginning of a violent motion as it is to study those stresses caused by continuous forced oscillation. Exhaustive studies of forced continuous oscillations have been made, but the stresses induced at the beginning of such motion are not so clearly understood by civil engineers.

According to Dr. Briske,‡ if the period of free oscillation in a building is 0.5 sec., there need be no fear of resonance because the period of oscillating motion in the ground cannot be expected to be less than 1 sec. In that case, the stresses would be the same as in a perfectly rigid building.

The writer showed that under exactly the same conditions the stresses in a simple elastic system are four times as much as in a perfectly rigid system. Then, if the period of oscillation of the ground is 1 sec., the duration or time interval of the first displacement will be 0.5 sec., which is equal to the period of free oscillation of the system. In Fig. 9** this is illustrated by the curve for the displacement ending at three units of time. The period of free oscil-

* Discussion of the paper by M. de Bussy, Esq., continued from November, 1928, *Proceedings*.

† Author's closure.

‡ The Hague, Holland.

§ Received by the Secretary, April 11, 1929.

‖ *Proceedings*, Am. Soc. C. E., November, 1928, Papers and Discussions, p. 2601.

¶ *Engineering News-Record*, Vol. 100, No. 17, p. 650.

** *Proceedings*, Am. Soc. C. E., May, 1928, Papers and Discussions, p. 1460.

lation of the system is π. Computations made by the writer have shown that the same increase in stresses may be expected in buildings. Even though a relatively prolonged oscillating motion of a certain period causes small stresses, the initial stress due to that motion may be much greater.

Contrary to the opinion of Dr. Briske, the writer believes that most of the higher buildings have a period of free oscillation far greater than "small fractions of a second". The Claus Spreckels Building, in San Francisco, Calif., which is nineteen stories high and which was designed for a wind load of 50 lb. because of the probability of earthquakes, has a measured period of 2.33 sec. In general, the high American office buildings cannot be expected to have periods of free oscillation of less than 1 sec.

Furthermore, the effect of the elasticity of the ground should not be neglected, because the bearing areas of high buildings are often small in comparison to their height. In an entirely new field of study it is dangerous to minimize, arbitrarily, the importance of unknown factors, such as the elasticity of the ground. On the contrary, the potential effect of these factors should be investigated first.

The remarks submitted by Mr. Wood,* especially in regard to the intensity of vertical motion, are of much interest. There is a general belief that vertical accelerations are of little, if any, importance, except when very close to the fault.

Professor Martel states:* "It may be that general limits, such as the range of periods and amplitudes of the oscillations, are all that engineers may ever hope to obtain."

In discussing another paper, Dr. Baily Willis declares† that it is impossible to determine the action of the earthquake force and that economic conditions will limit the transverse strengthening of buildings.

Even if a specific range of amplitudes and periods of oscillation were given by seismologists it would not help structural engineers very much. Methods will certainly be found for computing the stresses in a building subjected to a given motion of the ground. However, the difficulty is that, even when a theoretical earthquake is limited to a total duration of 10 sec., an infinite number of combinations of shocks or displacements, all of unequal magnitudes, may be assumed to occur during this interval. These combinations will cause low stresses if certain shocks counteract the effect of the previous shocks, but if all the effects are cumulative the result will be extremely high stresses. No builder could afford to make provision for these extreme combinations and, economically at least, he would be justified in not doing so because the possibility of their occurrence is almost infinitely remote. Economic considerations, therefore, such as the relation between risks and costs, must determine the degree to which the building is to be braced against lateral forces.

Referring, for example, to Fig. 6 (*c*),‡ if a constant acceleration causes a stress of one unit, the same acceleration applied instantaneously will cause a stress of two units. If the acceleration is reversed at precisely the right moment, the stress is increased to four units and further increases to six,

* *Proceedings*, Am. Soc. C. E., November, 1928, Papers and Discussions, p. 2603.
† *Loc. cit.*, December, 1928, Papers and Discussions, p. 2753.
‡ *Loc. cit.*, May, 1928, Papers and Discussions, p. 1457.

eight, etc., units, will take place if subsequent reversals are properly timed. It is doubtful, therefore, whether it will ever be possible to use seismological data for finding the absolute limiting value of the transverse forces to which a building may be ultimately subjected.

However, there is another phase of the problem which deserves further study. If a builder is willing to spend a certain amount of money for strengthening a building against earthquakes, he is entitled to know which of several ways is the best one in which to spend it. This raises the question as to the possibility of predicting something concerning the distribution of stress that has not been previously recognized in the art. It is futile to make one member excessively strong if another is relatively weak.

Suppose, for example, that methods are known for computing the stress in a building in terms of the motions of the ground, and that for a certain building project, these methods are applied, using a great number of combinations of ground shocks. If all the resulting stress diagrams are of the form shown in Fig. 13 (*a*), it is evident that the only way to make the building uniformly safe is to assume a straight line variation in determining stresses against which it is to be strengthened. The exact location of this line will depend on an economic consideration. If, on the other hand, all the stress diagrams that result from assuming different motions of the ground were found to be convex, the final curve chosen for this type of structure would have the same characteristic convex form (see the solid line in Fig. 13 (*b*)). The same would apply if studies for a certain building produced concave stress diagrams, such as those shown in Fig. 13 (*c*).

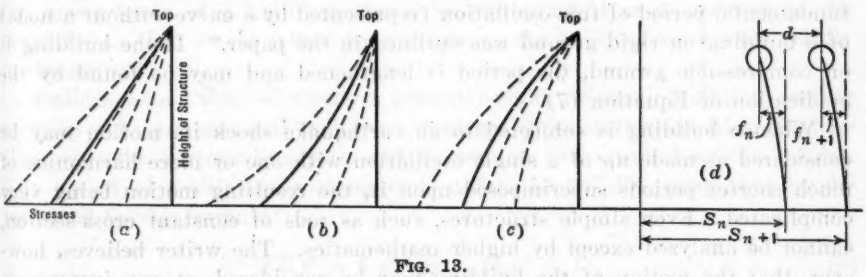

FIG. 13.

Admittedly it will not be as easy to select the proper shear diagram in practice as it seems to be in Fig. 13. The writer believes that further investigations will show very definitely that, in general, the full line curve in Fig. 13 (*a*), which represents common design practice, does not approximate actual conditions as well as that in Fig. 13 (*c*). In other words, he believes that the upper parts of buildings should be designed stronger, relative to the lower parts, than would be the case if the building, as a whole, is assumed to be subjected to horizontal acceleration, as in Fig. 13 (*a*).

The writer presents herewith in a condensed form, some of the arguments that support this belief, dealing specifically with two problems: (*a*) Simple elastic systems on compressible ground; and (*b*) flexible buildings on compressible ground.

Simple Elastic Systems on Compressible Ground.—In the paper the simple elastic system used for illustration consisted of a heavy mass at the top of an elastic rod which was fastened rigidly to the ground. The weight of the rod may be neglected. Let the rod now be fastened to a flat support or base, resting on the ground, or on some substance which is assumed to have elastic properties. The result of this change is that the system now has a longer period of natural free oscillation.

Let the subscript, a, denote incompressible ground and a flexible rod, and the subscript, b, a rigid rod and compressible ground. Then, using the original notation, the new period of oscillation can be determined by the relation:

$$(T')^2 = T_a^2 + T_b^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

There are not, as is often believed, two simultaneous increments of vibration, one due to the elasticity of the rod and the other to the compressibility of the ground. Except that the period of free oscillation is lengthened, there is no change in the behavior of the system. Whether it is subjected to sudden and reversing accelerations or to displacements, it acts entirely as the simple elastic system described in the paper. Therefore, a single displacement may cause stresses four times as great as those resulting from the complex acceleration alone. This actually occurs if the duration of the displacement is equal to the period of oscillation of the system. For example, if the natural period is 0.5 sec., the duration of the displacement must also be 0.5 sec., in order to cause this effect. Then, what is called the "period" of the earth shock must be 1 sec.

Flexible Buildings on Compressible Ground.—A method of estimating the fundamental period of free oscillation (represented by a curve without a node) of a building on rigid ground was outlined in the paper.* If the building is on compressible ground, the period is lengthened and may be found by the application of Equation (7).

When a building is subjected to an earthquake shock its motion may be considered as made up of a single oscillation with one or more harmonics of much shorter periods superimposed upon it, the resulting motion being very complicated. Even simple structures, such as rods of constant cross-section, cannot be analyzed except by higher mathematics. The writer believes, however, that the motion of the building may be considered, at any instant, as being mainly a simple oscillation, the amplitude of which will decrease or increase according to the nature of the consecutive shocks.

Computations made by the writer lead to the following conclusions:

(a) If the motion of the building is considered as being composed of a fundamental simple vibration and a number of superimposed harmonics, the fundamental vibration contributes by far the larger part of the resulting stresses.

(b) In general, the fundamental period of natural vibration of tall buildings is of the same order of magnitude as that of the period of earthquake shocks. Therefore, it is the fundamental oscillations of the building which are likely to be magnified. It is this fact that really creates the danger in

* *Proceedings*, Am. Soc. C. E., May, 1928, Papers and Discussions, p. 1462.

tall buildings. The harmonics of the motion of the building, on the contrary, have much shorter periods which are not simple ratios of the earth period. The stresses in the building due to these vibrations are relatively small from the very beginning and will not contribute materially to the total stresses. The stresses due to the fundamental vibration of the building, therefore, will predominate.

(*c*) Preliminary computations lead to the belief that Conclusion (*b*) will be greatly emphasized by considering the effect of damping. If the damping is such that the amplitude of the fundamental vibration of the building decreases during one full oscillation to nine-tenths of its previous value, the amplitude of the harmonics of the vibration will decrease to the same degree. However, since several (six, for example) harmonic oscillations occur during one fundamental oscillation, the amplitude of the building resulting from the former will have diminished to $(0.9)^6 = 0.5$ of its original value while the amplitude of the latter is still nine-tenths of the original. The same is true then for the stresses induced by the oscillations and the effect of the fundamental vibration will predominate.

Now, according to computations by the writer, the curve of shear stresses in a building subjected to its fundamental vibration is always very similar to that which results from assuming the building to be rigid and subjected to an angular acceleration about a horizontal axis through the center of its foundation. This form of curve, therefore, should be recommended for determining the forces against which the building should be strengthened. For a prismatic frame structure this curve is concave as in Fig. 13(*c*). In general, the upper levels of a building should be strengthened more, relative to the lower levels, than would follow from assuming the building to be fixed rigidly to the ground.

Buildings on Piles.—Consider a perfectly rigid, prismatic building, resting on piles that are assumed to have a constant cross-section, to have no friction with the surrounding soil, and to rest on firm ground at the bottom. The period of oscillatory rocking motion for the building may thus be determined by the formula:

$$(T')^2 = 4\,\pi^2\,\frac{\sigma}{E}\,\frac{l}{g}\,(4\,n^2 + 1) \qquad (8)$$

in which,

T' = period of rocking oscillation;
l = length of piles, in feet;
σ = unit stress, in pounds per square inch, in the piles due to the weight of the building;
E = modulus of elasticity, in pounds per square inch, of the piles;
g = acceleration due to gravity, in the same units as l; and
n = ratio of height to the width of the building.

It should be noted that the dimensions of the building enter into no other factor than n. To illustrate, let $n = 4$, $\frac{\sigma}{E} = \frac{1}{8\,000}$ (which is approximately

correct for concrete piles), and $l = 30$ ft. Then,

$$(T')^2 = 4\pi^2 \times \frac{1}{8\,000} \times \frac{30}{32.2} \times (4 \times 4^2 + 1) = 0.3 \text{ sec.}$$

and,

$$T' = 0.55 \text{ sec.}$$

If n is increased to 6 (which is fairly common for tall buildings), T' increases to 0.82 sec. As has been stated previously, the elasticity of the building increases the period of vibration so that periods of 1 sec. or more will often occur.

Complying with the request of Professor Martel,* the writer submits his derivation of the formula by which the diagrams referring to the simple elastic systems were plotted.

Consider a horizontal force, P, to be acting at the upper end of the rod so that the resulting lateral displacement at the top is f. Since the rod is assumed to be elastic, the ratio between P and f must be constant; that is, $P = cf$. On the other hand, when the rod has deflected a distance, f, at the top, it will exert a force, $P = cf$, on the mass. This produces an acceleration, a, as determined by the relation,

$$a = \frac{P}{m} = c\frac{f}{m} \quad \ldots\ldots\ldots\

Further, from Fig. 13 (*d*):

$$d = (S_{n+1} - f_{n+1}) - (S_n - f_n) \quad \ldots\ldots\ldots\ldots\ldots\ldots (13)$$

Confirming Equations (12) and (13):

$$(S_{n+1} - f_{n+1}) - (S_n - f_n) = \frac{c}{m}\left(\sum_1^n f - \frac{f_n}{4} + \frac{f_{n+1}}{4}\right)(\Delta t)^2 \ldots (14)$$

In all his computations the writer assumed values for $\frac{c}{m} = 4$ and for $t = 0.25$, respectively. Introducing these values and making further simplification, Equation (14) becomes:

$$f_{n+1} = f_n + \frac{16}{17}\left(S_{n+1} - S_n - \frac{1}{4}\sum_1^n f\right) \quad \ldots\ldots\ldots\ldots (15)$$

During the consecutive intervals, the values of $(S_{n+1} - S_n)$ must be computed first; they result from the assumed motion of the ground. The corresponding values of f, Σf, and $\frac{1}{4}\Sigma f$ can be arranged in tabular form for convenience. For the numerical values, selected by the writer, Equation (15) proved to be sufficiently accurate for practical purposes.

The following additions and corrections will serve to clear up misunderstanding in the text of the paper. In Fig. 3*, the abscissa values, 0, —0.5, and —1.0, should be moved to the right so as to appear at the ends of the dotted lines, 4, 5, and 6, respectively. Curves 1 and 7 in this diagram represent the assumed full transverse strength of the building throughout its length; Curves 2 and 6 represent one-half, and Curves 3 and 5, one-fourth, that strength.

In Fig. 5†, the curve for the ultimate transverse strength of the chimney would fall mostly outside the diagram. Therefore, only the curves representing 0.3, 0.2, and 0.1, of that strength are shown. The full-line curves represent the bending moments caused by a horizontal acceleration of 1 ft. per sec. per sec., at the base. For other values, the ordinates in Fig. 5 must be increased proportionately; that is, for 5 ft. per sec. per sec., multiply the ordinates by 5. When $z = 40$, the full line curve for this value almost corresponds with the dotted curve giving 0.2 of the ultimate bending moments at four-tenths the height of the chimney. If the acceleration was increased to 5 ft. per sec. per sec., this curve would nearly coincide with the curve of full ultimate bending moments. Under these conditions the chimney would fail. In Figs. 2‡, 9§, and 10§, the use of the letter, T, to designate time, should not be confused with its proper function which is to designate a period of oscillation. In Fig. 11‖, T is properly used.

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* *Proceedings*, Am. Soc. C. E., May, 1928, Papers and Discussions, p. 1454.
† *Loc. cit.*, p. 1456.
‡ *Loc. cit.*, p. 1453.
§ *Loc. cit.*, p. 1460.
‖ *Loc. cit.*, p. 1461.

AMERICAN SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

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REPORT OF THE COMMITTEE OF THE IRRIGATION DIVISION ON "A NATIONAL RECLAMATION POLICY"

Discussion*

BY MESSRS. CHARLES R. HEDKE, CHARLES KIRBY FOX, RHODES E. RULE, AND GEORGE M. BACON.

CHARLES R. HEDKE,† M. AM. SOC. C. E. (by letter).‡—An expression of opinion from engineers whose major experiences were obtained in irrigation, on a policy which embraces the basic principles which they now believe should govern, in the future, the National Reclamation Policy, would be valuable and would carry authority and weight in the solution of a very important problem. Such, doubtless, was the aim of the Executive Committee of the Irrigation Division when creating the Committee. Furthermore, to clothe the report offered with the endorsement of the entire Irrigation Division is a worthy effort, but it cannot go unchallenged, because it is felt that many interested members have not been satisfied by the report as a whole. Several of its principles are suspected of error equal to those in the present policy and, what is more serious, the report does not reach far enough to correct the vital and underlying weakness in National reclamation. A most general review of the experiences and lessons from past results seems clearly to justify one viewpoint at least, namely, that the entire problem is much more serious than the curt report of the Committee would indicate. The "Explanatory Statement",§ issued by the Committee as supplementary, is also not satisfying. It should have preceded the report and should have contained more data and arguments to support some of the principles used.

A policy for a National problem as large as reclamation cannot be framed by stating merely the engineering features involved. Clearly, it must include

* Discussion of the report of the Committee of the Irrigation Division on A National Reclamation Policy, continued from September, 1929, *Proceedings*.

† Cons. Engr., San Antonio, Tex.

‡ Received by the Secretary, July 8, 1929.

§ *Proceedings*, Am. Soc. C. E., May, 1929, Papers and Discussions, p. 1193.

other and vastly different fields of endeavor. Nevertheless, engineers have been largely in practical control of Government reclamation; they have guided the affairs of that undertaking and are, therefore, responsible in a very large way for the results obtained.

Somehow, National reclamation has not been an outstanding success in itself. There are many who feel that it should have been successful, and, therefore, several attempts have been made to ascertain the reasons for the developed weaknesses in order to propose changes and remedies. The Special Advisory Committee appointed for the Secretary of the Interior to investigate the results of National reclamation and to recommend changes in the policy, gave considerable time and thought to the problem. It proposed corrections which provided a tendency of direction apparently not in line with the opinions of the Committee of the Society. This Society Committee, furthermore, is at variance with the present National policy in some of its original principles.

The Committee of the Irrigation Division doubtless represents a wide range of opinion and is, therefore, entitled to considerable respect. It follows readily, however, that the engineers directly attached to the problem are as well qualified to pass judgment as the Committee. Between these two groups there are apparently some differences of opinion, not as clearly expressed as they might be, and which must be reduced to a clearer understanding before the members of the Irrigation Division can vote intelligently on the report. There is evidence of another group, comprising those who cannot reconcile their experiences with the new principles of the Committee, nor with the present policy of National reclamation. A training that touched the early field of private irrigation enterprises and their financing and grew upon the fundamentals developed from those efforts cannot easily rid itself of certain lessons derived from the successful irrigation developments in the country. Neither can the engineer, with experiences derived from contacts with problems of large financing, reconcile the lack of principles for the security of cost payments under Government reclamation with the statements made of the great values created by these developments. It is sincerely hoped that some of the richer experiences from both these classes of engineers will be applied to the problem under discussion.

The following viewpoints and conclusions are offered in defense of the principles underlying private irrigation enterprises. In presenting these in contrast with the principles of the Committee and the Government no spirit of personal criticism is intended and it is only hoped that some thoughts will be given which may disclose a new application for an old principle, or suggest to the members of the Irrigation Division the deep and serious matters involved in the report. Only the principles that cover the apparent differences between private irrigation developments and Government reclamation will be included.

Principles Underlying Private Irrigation Developments.—The final test as to the feasibility of every reclamation project must lie in the answer to the question: Can it be made to pay? In that answer are involved all the engineering features, all the farm development features, and all the operating features of the project (including its farming), balanced with all the economical soil production features of the entire country. The first three of these can

usually be reduced to quite definite figures, representing one side of an equation as costs with profits and loss, while the other side contains the doubtful factors of probable values and returns. The weight of the doubtful side of the equation must still enter the final decision, not as a set of definite figures, but rather as a feeling based on experiences obtained from contacts in the broad field of business. The simplest irrigation developments (those intended for the production of native hay in the mountain valleys) and the most complicated developments of private and Government projects should go through the same steps of investigation to reach the final answer regarding feasibility. The following test question is not unfair and should be kept in mind: Has this practice been followed as thoroughly for Government as for private reclamation?

Farm production costs and the business of farming are not yet as clearly understood among engineers as might be expected. Statistics on the business of farming are easily obtained, which tend to show that it is not attractive nor profitable. At present (1929), so much is heard about "Farm Relief" that care is necessary to prevent ideas from becoming distorted and unsound in considering the principles underlying irrigated agriculture. Farming, when considered on the average American business basis, is doubtless not profitable and, what is more important, it has never been profitable in the American sense of the word. Something beyond the strict business of farming has enabled that industry to exist, and even to attract people and grow to its present status in which it has the weight to undertake measures to better its condition.

The present farm relief effort reaches much further and has a much deeper meaning than temporary relief for the farming industry. It is clearly intended to Americanize the industry and the underlying hope is founded on that vision and faith which has made other American industries grow and prosper. Farming in consequence has a much better prospect now than ever before and both private and Government reclamation advocates can revise their estimate of the need and can urge underlying irrigated agriculture. However, the economics of the farming industry were the same when the large areas of private irrigation enterprises were built as when the Reclamation Act was passed, and they have continued much the same to the present time. The business of farming cannot be blamed for the difference of success existing between private and Government reclamation. There is something else that is wrong.

Controlling Differences Between Private and Government Reclamation.—The waiver of the interest charge, as provided under the original Reclamation Act, now appears to be blamed, under the principles of the Committee, for the failure of the repayment of costs to the Government. The underlying reason for taking that position must arise from the subsidy feature which the Committee has attached to that financial concession. No discussion is given which justifies its viewpoint and apparently it was accepted so readily by the Committee that any contrary view might receive scant consideration. Nevertheless, the writer wishes to direct attention to the much more plausible reason which can be given to the "no interest" feature, when it is considered to provide

an offset for the financial differences, anticipated as natural and inherited, between Government and private reclamation.

First.—The approach to every private irrigation enterprise is through its ability to create some underlying values and make some money. This always furnishes the urge for the development. The approach for every Government project is clearly through politics. This furnishes the final force which determines the time and place for every Government development.

Politics recognizes but little economic difference between the project with a climatic location of 4 000 day-degrees of heat available for the growing of crops and one with 10 000 day-degrees, or between a project with an estimated cost for water development of $60 per acre and one for $120. There is, nevertheless, a wide economic difference between a project that has 10 000 day-degrees of growing heat available per year under a water cost of $60 per acre and another project that has 4 000 day-degrees under a water cost of $120. Private enterprises have always faced and met, as far as possible, the economic adjustment necessary between the ability of a project to produce and the ability of the project cost to produce. The forces of politics in Government projects superseded the forces of economics in private projects and, in consequence, there was imposed, at the outset, an unequal inherent difference in the ability of the projects to pay.

It was clearly the field of the engineer to equalize this difference as far as possible in the original set-up of the projects, but equalization was apparently disregarded then and its correction is now attempted by concessions and releases. Claims for adjustments of this character underlie the inter-project feeling for an even break from the National Government. There is little to be gained by citing the success of several Government projects in contrast with the many marginal ones. For example, the water users in Montana instinctively feel a grievance against the Government for the handicap imposed on them when their results are so often compared with those of the water users in Arizona and New Mexico. Government reclamation has been treated as one large undertaking, made up of many large units, and there is now no escape from the resulting viewpoint of reasonable equality and justice from the Government.

Second.—The next difference existing between private and Government irrigation involves the bases and principles used for the value and ownership of water.

The principles developed from private irrigation, as reflected by the laws and Court decisions in the arid States, revolved around the viewpoint that water had a distinct and separate value and that ownership was as positive and actual for the water as it was for the land. The principle that ownership of water could only be obtained through its use was much the same as that applied for the acquisition of public lands from the National Government. These principles simply mean that for undeveloped public property, where additional values were created through private effort, ownership could well be given to all. The transformation of the water in a stream into the products from the soil made additional values for both water and land and thereby created the reason for ownership to both. It followed naturally, from private

enterprises, that the maximum value of water was obtained from the maximum crop value per acre and not from the greatest number of acres that water could be made to cover. It was a principle established by private enterprise to let the value of the water adjust its economic application.

The practical application of these principles somehow was lost under Government reclamation. The settler on a Government project was given the impression that the payments contracted for by him were for construction only and that they attached to his land. Water value and its ownership were never made clear to him. In early mutual enterprises the fundamentals regarding water became so clear that confusion was never possible thereafter. Private owners did their own work of construction for water and it then represented a tangible asset of considerable value. Under extended developments, in which some money for construction was borrowed for short periods, water value was still held clear and definite, because the security for the personal notes used was taken on the value of the water more than on the value of the land held by the borrower.

There are sections in this country even to-day (1929) where the collateral for all the usual farm loans is the water stocks available. They are well suited and liquid assets and they have a ready market because the conditions with which these companies have surrounded their stock make it possible to buy and sell that ownership and transfer its use within reasonable limits. The principle of water value and ownership was carried still further by them under complex stock companies which arranged to borrow considerable money and gave as security a mortgage on their property, works, and water rights, which clearly represented water value. Sound development was made on this basis everywhere in the West.

The first step toward National reclamation, represented by the Carey Act, was based on the principle of water value and is sound fundamentally to-day, no matter what its minor weaknesses may be. The Irrigation District method for water development appeared next; it superseded the National Reclamation Act. It was based on the plan of using the land as additional security for the water loan. Somehow, it now appears that this feature led to the viewpoint that the land was the most important if not the only asset, and, in consequence, much trouble was encountered by irrigation districts. Next appeared National reclamation, by means of which the settler was given the land and the water value was not recognized as any collateral so there was in reality no security for the cost of the water development. In fact, the entire procedure made it appear to the water user (as he was most unfortunately called) that what he was expected to pay for was a license or a concession charge for the privilege of farming on a Government project. Such certainly was not the intent of the law and some fundamental principle was clearly overlooked or disregarded to create such a result.

No principle is outlined in the report of the Committee that provides any change toward a security of any kind whatever for the repayment for Government cost of water and, therefore, the report has not reached the fundamental source of National reclamation difficulties. The present tendency in State irrigation district laws is more and more toward the personal-ownership

aspect for water and value and if that principle is sound for irrigation districts it may be well to consider it for National reclamation.

Third.—In this section the difference discussed relates to comprehensiveness in private *versus* Government reclamation. It still appears to be the general opinion that the remaining opportunities for irrigation developments in this country are too large; that the cost repayments are impractical for private enterprise to undertake; and that the National Government alone can do this work. Within the meaning of private enterprises, which is taken as everything other than National and State developments, it should be remembered that about 90% of the total irrigation of the country has been accomplished. The viewpoint controlling comprehensiveness, as provided from the experiences and results of private work, is quite different from that used for National reclamation.

Private enterprises first made use of the water from the normal flow of the streams. When this flow became insufficient a supplemental supply was provided by small reservoirs which were filled from the flood flow. When the practical limit of diversions from the average seasonal flood flow was reached, the next step consisted in providing a large reservoir, situated in the bed of the stream, which was used for the hold-over supply from large to small run-off years. In that manner the entire available water supply was developed under the continual influence of the demand for more water by having additional land directly available. The period intervening between the use of normal stream flow and the creation of large reservoirs has been a long one in private developments.

In the meantime, a most important result of irrigation was disclosed. Return waters, obtained naturally or from drainage, were found to be considerable and their re-use introduced another stage in comprehensiveness. The private method for stream development consisted of four distinct stages; took many years to complete; was financially sound for each step, since the method itself created the demand for the water; and the final costs were less than under the one-stage Government reclamation method. Comprehensive development was actually reached through the four-stage method; it has been far from complete in the case of the Government method.

Comprehensiveness in Government developments clearly consisted in reaching for the limit of the physical features involved in each project at the outset. No hesitancy is apparent on the part of the Government in going as far as possible; (*a*) for size of storage attached; (*b*) for size of distribution provided; (*c*) for permanency of construction furnished; and (*d*) for such other features which appealed to the public of the section, equalized the expenditures between the benefited States, and involved large sums of Government money. No attempt was made to start anything smaller which would grow larger as financial strength was created by water demand from sound farm developments. The basis used for the physical set-up was wholly in keeping with all Government undertakings, and there resulted a depressing effect because the projects never became economically adjusted between water supply and demand.

This uneconomical feature in Government comprehensiveness resulted also in depressing private irrigation which was directly discouraged by the large

water filings made and embargoes imposed. A correction for this condition appears in the principle now generally advocated which provides that the Government undertake only the construction of the controlling feature in any stream development, such as hold-over reservoirs for flood control, power, and water supply, and that water be sold thereunder to all approved users when and as the demand exists, whether they are municipal, irrigation, or power organizations, whether they are large or small, and whether the projects are existing developments or new ones. The concept for Government comprehensiveness appears to be changing to Government conservation; therefore, some unwise feature must have been operating in the former basis.

Fourth.—Another difference exists between private and Government viewpoints in regard to the aspect of land inclusions under a project. This affects directly the marginal lands. Because of their topography, soil, economic development costs, or economic location in the project, these lands are seen to be unable to stand the cost of the water-supply burden by the owner or settler, at least during the beginning period of the development. The existence of such marginal lands under Government reclamation is now doubtless indicated by the 28% of the land idle on the projects. They clearly represent a heavy dead load. The reduction of this load has apparently been slow and difficult and has created the major problem for the present Reclamation Commissioner.

Managers of private irrigation enterprises fundamentally base their unit costs on the unit of water supply available or developed. They may convert that figure to an acreage basis, but acreage is never the controlling factor in their computations. Their projects have grown strong and sound on the water-value principle and its practical application has provided the natural and automatic exclusion of all lands not suitable to stand the cost of the water burden. Water is the commodity product of private irrigation, and its use has been allowed where and in those quantities that best suit the buyer of the product. The market for the product is considered carefully and is always one of the controlling features in determining feasibility.

Government reclamation definitely attached the water to the land. Wherever this attachment was suspected of being unable to transform the potential values of both water and land into actual values, sufficient to make them attractive, both have remained unused and, in consequence, the attachment seems unsound. Fixing the place of use for water by any one other than the party paying for it, is unwise according to private irrigation principles. Water and land must go hand in hand, each assisting the other; it takes both, used jointly, to transform their potential values into actual values. Increments in the value of each are the objectives of private irrigation.

Attaching the entire increment of value created by irrigation, whether potential or actual, to the land is unsound according to private irrigation experience. Land speculation simply consists of attaching an unearned increment of value, due to possible irrigation, with some or even all of the water value, to the land. Speculation was really aided under Government reclamation by having the value of the water unencumbered, because it was unrecognized, and therefore it was easily attached to the land by others as an unearned land value. Land speculation has never been serious in places where there

was any fair excess of land to which water could be applied and on which it must be used in order to get any substantial increment of value.

No unsound colonization is possible when the provision is made that the entire increment of water value (due to its use and above its construction cost) is arranged to accrue to the user of the water. The best control for sound development, as seen from the lessons in private enterprises, is to have available considerably more land than the available water can possibly cover, with the further condition that the right to the use of the water will accrue to the first in time of use and payment of cost. A principle which would provide a sound economic relation between the areas of land and the water available for Government projects will correct much of the weakness inherent in such projects.

Fifth.—The standard of engineering for the construction of Government reclamation projects is now generally accepted as the standard of the country. Credit and praise must be accorded the Engineering Profession, and the Reclamation engineers in particular, for the character of the works built. Substantial and lasting benefit has resulted to private irrigation from the problems of design and construction solved under this development. However, engineers in private practice have never been able to dovetail all the Reclamation standards into any one project and fit them into a cost analysis acceptable to the owners and backers of private enterprises. The Reclamation standards are not in line with the experiences and results obtained in private developments. Private enterprises must obtain their initial water cost as low as possible because (1) margins are computed as more than this cost; (2) the prevailing interest charge equals the original cost in about fifteen years; (3) the true direction and tendency of the best suited system of cropping for the area are disclosed in about fifteen years; and (4) because a value will be created for the re-use of return waters sufficient to pay for the cost of the drainage. These four reasons all converge for a readjustment of the construction and financing of a project at some later period and hence the permanency of construction can be made more suitable and economical at that time than can ever be anticipated in the beginning.

The principle that the permanency of construction shall more nearly parallel the values created by its use has resulted from private developments. This is clearly in line with all private developments and, more particularly, with farm developments. Confusion should not be made between permanency and safety. National reclamation inherited a high standard for its construction just because it was National Government work. No other basis was possible and the statesmen responsible for the Reclamation Act doubtless knew such would be the case. The time-honored standards for all Government work were imposed on National irrigation at the outset and a burden thereby resulted that was not attached to similar private enterprises. To justify and offset that inevitable condition may be one of the reasons why the law-makers provided for the waiver of the interest charge.

The principles that create the differences between private and Government irrigation enterprises may be summarized in ten items. Private developments provide that:

(1) The broad foundation between the natural and economic forces involved should be made sound.
(2) Water is a National natural resource like land and should be treated in all economic and legal aspects as being similar to land.
(3) Comprehensiveness is best obtained by separate steps, each of which should be made financially sound before the next is taken.
(4) Because there is much more land than water available in the arid region, conditions should be provided that only the best lands, under an economical project set-up, will ultimately secure the use of the water.
(5) The permanency of construction should be made parallel to the values of the water they create.

In contra-distinction to Principles (1) to (5), the following refer to National irrigation, which uses:

(6) Political expediency for projects, instead of economics.
(7) The "forever public" ownership of water basis, in its security aspect for water value.
(8) National comprehensiveness, instead of public conservation.
(9) The inseparable relation of public water to land, in its appropriation basis.
(10) Permanency of construction in line with other Government construction, in its work of reclamation.

It is apparent from Principles (6) to (10), inclusive, that: (1) Most of the fundamental and controlling forces underlying National reclamation are quite natural and inherited; (2) they all operate quite differently than those underlying private enterprises (Principles (1) to (5)); (3) they all circumscribe results and add burdens; and (4) undoubtedly the statesmen responsible for the Reclamation Act instinctively felt these differences and knew their financial effect so that they met it, in the best manner possible, by waiving the interest charges. It appears to be a strong case of attempted equalization and adjustment and nothing like a subsidy in any possible sense. It seems to be entirely wrong to change that interest waiver feature until the principles underlying National reclamation are changed. Viewing that feature in this manner leaves no basis for an alleged subsidy and consequent paternalism stressed by the Committee. In fact, a thorough analysis of the inter-project value for the financial offset through the interest waiver feature may disclose more inequalities and may show that some projects are entitled to even greater concessions before they are on a par with each other and with private enterprises. This much seems certain: Whatever waivers, releases, and concessions have been given thus far, to the various projects, they were well founded and were justified under the inherent conditions attaching to National reclamation.

The interest offset feature in the present policy is still wise and will remain so until a better understanding is had of its true meaning. The principles of protection and correction are introduced and admitted by this feature and it will remain such until a sound economic adjustment is made of the whole problem. It is the wisest feature in National reclamation because it will some day straighten out forever the absolute foundation of irrigation, namely, the economic and legal aspect of water. It does not subsidize the remainder of agriculture for the benefit of the few who have been experimented upon for

National reclamation. The Committee has not reached the underlying weakness in National reclamation by its principles for a new policy.

It may be well to return to the subject of irrigation districts. Organized under State laws, these districts have been given a quasi-public character and, in consequence, their leaders have had a tendency to follow along the lines of National reclamation in the matters of value and ownership of water. Furthermore, they have been supervised by the States which introduced the features of water conservation, project comprehensiveness, and construction permanency, along the lines of the National policy. They were then, through necessity, so set up and "geared" that a burden was imposed on the present to conserve and provide something for the future. Wherever this burden has been too great the irrigation districts have had difficulties. Wherever an offset feature was provided to relieve those imposed conditions the difficulties have been less. The waiving of the interest charge was not possible nor practical for them, but, nevertheless, some other offset feature, having the same result, must be introduced and made effective in order to insure that such projects may become sound and feasible.

This offset feature may take the form of an income from a hydro-electric by-product wherever possible, or as revenue from the taxation of property that has been benefited by the development and doubtless other ways and means will present themselves. The whole field of irrigation district experience has made it clear that some offset must be provided wherever any tax is imposed for requirements beyond the immediate and strictest reclamation needs of the new settler. New irrigated agricultural developments alone cannot stand the burden of conservation, comprehensiveness, and permanency, and where these burdens have been added to reclamation the entire experience therefrom shows it is unwise to attempt it. The interwoven character of the farming industry with the other industries of the country makes it reasonable to consider that even the entire industry should not alone stand that burden. It appears that there should be some principles in the report designed definitely to allocate burdens, if Principles (8) and (10) are considered essential.

The National Government rightly and naturally should assume the original ownership and control of the natural resource of water. Some of that resource should rightly and naturally be then turned over to the individual States, and it follows readily that some of it should be made inter-State. When, however, the character of that resource becomes so complex as to involve many States, and its control is so interwoven that responsibilities become unnatural, even for inter-State relationship, then the National Government must exercise its parent duty and step in to meet the problems involved. The plan for Mississippi River control is then clearly National and is primarily intended for protection to large property values and many people. The Boulder Dam situation is still a project, while the control of the Mississippi River is a problem, and Congress evidently has taken that view of them. The principles suggested for the control of floods offered by the Committee are not sufficiently clear to provide a basis for the allocation of the costs entailed and it is suspected a considerable problem is involved therein.

The stressing of the economic aspect of the agricultural industry seems out of proportion in the report of the Committee. The cropped area of Government irrigation, in a quarter of a century of effort, represents less than 0.4% of the cropped area of the country. The idle lands mentioned by the Committee as existing in the Rocky Mountain area and along the Pacific Coast are doubtless nothing more than the marginal lands which have been found unprofitable under the changing conditions of supply and demand through the general development of the country. That process of elimination has been going on for a long time and will continue, because lands which once were profitable only on account of their location to markets, have become unprofitable under the extension of the transportation systems of the country. Every agricultural area is now able to compete effectively with every other area, as far as its availability to markets is concerned, and, therefore, the profit problem is resolving itself more and more into determining crop adaptability, or the ability of Nature to produce. Consequently, some areas are certain to become idle when faced with fundamentally adverse conditions.

Adjustments of like character have gone on in every industry and must be faced in agriculture. There is certainly a benefit to an industry to furnish conditions in which it is possible to produce output values 2.5 times as much as the average. It is a significant fact that irrigated agriculture is in the lead for value of gross production per acre in the industry. It is, therefore, the soundest basis for farming in the country and so if any curtailment is made, it is clearly in error to place it there. Land settlement is becoming more and more a problem of creating advantages in one location over that in another, for the people already in the farming business. The arrival of a new settler, on an irrigated project, does not necessarily mean that he is a new farmer.

In conclusion, it is evident that National reclamation is still an experiment. It is apparent that every one concerned with the problem, including the land owners on Government projects, desires changes. Some of the suggestions offered are so fundamental that a wide departure from the present policy is involved. It would seem to be a sound beginning policy to undertake correction of existing projects first. The act of postponing all new projects might develop some weight for the step but this should clearly be understood to be for no other reason than first correcting wrong tendencies in the present policy. Correction seems a case for education, involving so many phases of the problem that it must start at the bottom, where it is believed the most difficult part of the problem lies. Engineers have had so much to do with this Government undertaking that they can well afford to busy themselves to bring about the first changes. Congress has been lenient, but not complimentary toward the results obtained. That unwise things have been done to date is no serious criticism. The principle of waiving of interest charges is considered and agreed to be an unsound financial policy and should be among the first of those corrected. However, merely to remove that feature, simply because some one considered it a subsidy, will not correct the present weakness in National reclamation. Finally, that feature is luckily in the present Reclamation Act and policy of Congress and is considered to represent a far-reaching principle of correction, wisely introduced by real statesmen, for the missteps in the

march of progress, and, therefore, in it now lies the greatest hope for the solution of the fundamental problems involved.

CHARLES KIRBY FOX,* M. AM. SOC. C. E. (by letter).†—Numerous timely and important papers on irrigation and related subjects have recently appeared in *Proceedings,* but for some reason the climatic conditions and the relation between the acreage cost of the system and the gross acreage crop values seem to have been overlooked.

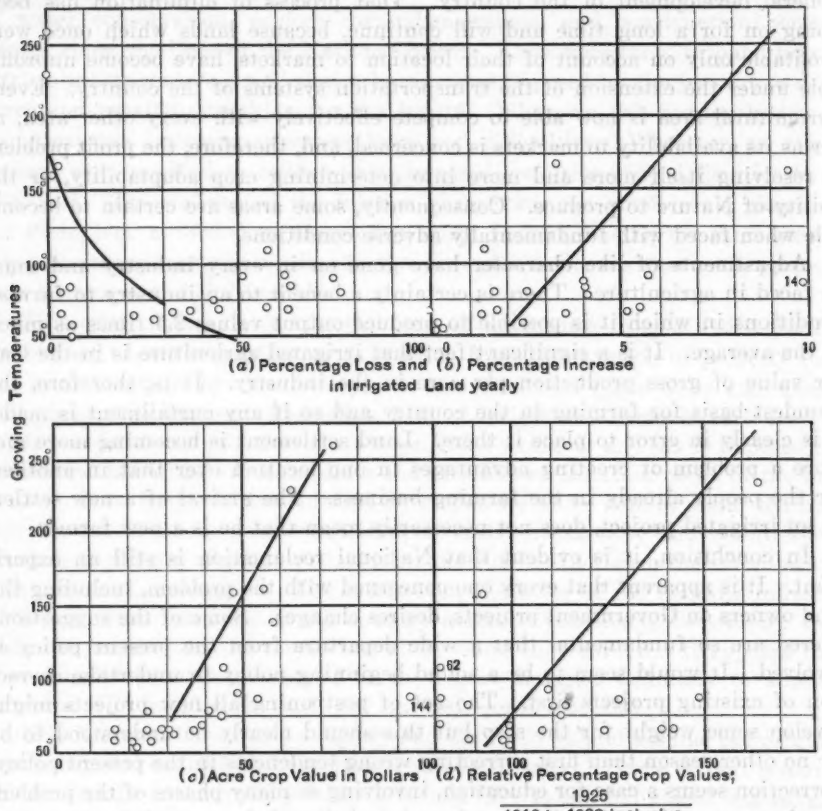

FIG. 1.—CROP AND IRRIGATION DATA FROM RECORDS OF U. S. RECLAMATION SERVICE.

Some time ago the Reclamation Service published data relating to the costs, crop values, etc., of its projects. These data are available for quite a period of years, over the entire West, and presumably are comparable, since they were compiled by one organization. The Reclamation Service Fact Finding Commission compiled data relating to the losses, etc. In Table 1, the writer has approximated the mean monthly temperatures from the U. S. Weather Bureau records (see Column (2)). The values in Columns (11) and (15) are from the annual reports of the U. S. Reclamation Service. Columns

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† Received by the Secretary, July 19, 1929.

TABLE 1.—COMPILATION OF CROP AND IRRIGATION DATA FROM THE UNITED STATES

TABLE 1.—Compilation of Crop and Irrigation Data from the United States Reclamation Service Records.

Project No.	State and name of project.	(1)	Growing (mean monthly temperature plus 50°) temperature. (2)	Net construction cost to June 30, 1928. (3)	Definite and probable loss. (4)	Percentage loss (definite and probable). (5)	Original estimated irrigable acreage. (6)	Area irrigated, 1928, in acres. (7)	Percentage irrigated. (8)	Years water has been available. (9)	Percentage of increase in new land yearly. (10)	Percentage of project completed. (11)	Cost per acre irrigated. (12)	Approximate cost per acre for completed project. (13)	Yearly maintenance cost per acre irrigated. (14)	Number of water users, 1928. (15)	1918-28 (10-year), average crop value per acre. (16)	Percentage of crop value to cost per acre irrigated. (17)	Percentage of crop value to final acreage costs. (18)	1928 crop value per acre. (19)	Percentage of $\frac{1928}{1918\text{-}28}$ crop values. (20)
1	Arizona—Salt River		230	$10 548 119	0	0	200 000	203 300	102	17-5	8.5	100	$51.90	$48.70	.....	4 250	$62.37	121	126	$108.05	163
2	Arizona-California—Yuma		260	9 026 547	0	0	76 966	53 970	70	17	4.1	95	167.45	88.00	$4.94	1 211	74.00	44	89	84.56	114
3	California—Orland		160	1 091 796	0	0	17 000	15 120	89	14	6.3	85	72.20	60.00	3.08	668	48.95	68	82	44.55	91
4	Colorado—Grand Valley		92	4 017 922	$2 105 087	50.4	53 000	12 870	23.3	9	2.6	824	324.80	90.50	4.40	389	48.74	15	54	52.89	108
5	Colorado—Uncompahgre		75	6 715 074	2 801 582	41.9	100 000	64 780	64.7	16	4.	984	103.60	68.50	2.12	8 639	44.56	43	65	49.47	112
6	Idaho—Boise		80	12 731 410	495 369	8.9	371 700	112 000	30.2	18	1.7	99	113.70	88.00	2.80	2 686	40.26	35	106	35.47	88
7	Idaho—King Hill		72	1 881 391	818 982	43.5	15 000	6 440	43.	3	14.	567	292.15	104.00	6.60	2 454	39.21	13	38	30.76	78.3
8	Idaho—Minidoka		65	8 054 668	141 969	1.75	121 000	105 590	87.	17	5.1	918	76.20	62.00	0.93	454	87.07	49	60	51.40	168.3
9	Montana—Huntley		65	1 474 409	888 623	60.4	35 000	19 520	55.8	16	3.5	897	75.50	50.00	2.46	578	31.72	42	63	38.57	123.
10	Montana—Milk River		60	6 763 083	824 845	56.6	251 906	18 170	7.2	13	0.55	79	372.20	43.20	4.45	178	16.80	5	39	15.	89.
11	Montana—Sun River		50	4 245 843	257 471	6.1	256 000	20 530	8.1	15	0.54	447	206.80	49.80	1.83	377	20.92	10	42	20.25	97.
12	Montana-North Dakota—Lower Yellowstone		65	8 110 449	989 271	31.8	66 000	15 600	23.6	14	1.7	91	200.00	65.00	1.82	572	24.75	12	38	35.14	142.
13	Nebraska—North Platte		65	18 672 160	2 887 864	20.6	129 270	111 250	86.5	16	5.4	70	122.90	158.00	1.71	1 685	30.00	23	19	81.91	106.
14	Nevada—Newlands		80	6 966 476	5 349 660	76.3	370 000	44 960	12.1	18	1.5	49	155.45	58.50	2.42	788	25.27	17	44	27.35	110
15	New Mexico—Carlsbad		105	1 393 995	45 897	3.3	20 000	24 060	120.	17-4	9.2	97	57.90	57.50	2.40	474	45.00	77	77	62.69	139
16	New Mexico-Texas—Rio Grande		140	12 146 114	43 158	0.35	175 000	89 590	51.2	16	3.2	73	185.60	100.00	3.00	3 204	48.18	35	48	87.65	182
17	North Dakota—Williston		65	460 107	.....	100.	8 797	1 590	18.	16	1.2	64	290.00	82.00	17.80	76	29.22	10	36	.....	.....
18	Oregon—Umatilla		110	2 683 400	1 539 026	57.	20 140	13 270	65.	16	4.1	969	202.00	79.00	3.30	544	45.51	23	58	28.32	62.2
19	Oregon-California—Klamath		55	3 974 464	233 395	5.9	236 401	86 000	15.1	17	.9	77	110.40	33.20	1.67	412	20.31	18	61	20.13	99
20	South Dakota—Belle Fourche		65	3 547 045	1 279 199	36.	79 000	31 150	39.3	16	2.45	84	113.85	42.50	1.27	988	17.14	15	40	10.78	98
21	Utah—Strawberry Valley		88	3 466 968	0	0	60 000	30 820	51.2	9	5.7	84	112.50	69.80	0.80	2 400	53.96	48	78	43.82	80
22	Washington—Okanogan		85	1 302 162	820 173	63.	8 650	5 570	64.5	16	4.	85	238.80	160.00	6.95	493	144.25	62	90	214.13	149
23	Washington—Yakima		85	12 161 982	381 192	3.15	181 769	123 700	68.	17	4.	96	98.30	79.00	2.00	4 365	93.31	96	107	118.18	127
24	Wyoming—Shoshone		55	8 290 865	2 249 612	27.2	110 000	42 780	38.8	16	2.4	54	193.80	102.00	1.60	935	25.96	13	25	25.61	99
	Total, or average		.....	141 787 096	27 102 287	19.0	3 056 427	1 202 130	39.4	.....	.....	.....	117.94	.....	.....	31 463	47.50	....	....	61.65	130

(3), (6), (7), (9), (12), and (14) contain data from the *Reclamation Record** and the data in Columns (4) and (19) are from the *New Reclamation Era*.†

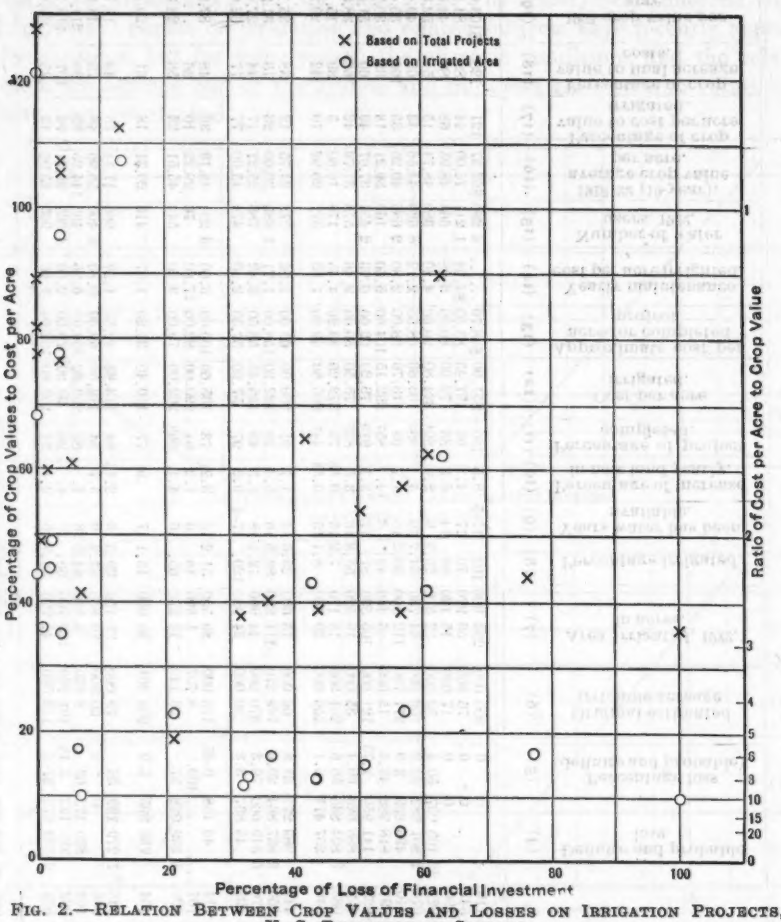

FIG. 2.—RELATION BETWEEN CROP VALUES AND LOSSES ON IRRIGATION PROJECTS, U. S. RECLAMATION SERVICE.

The remainder are computed as follows: Column (5) $= \frac{\text{Column (4)}}{\text{Column (3)}}$; Column (8) $= \frac{\text{Column (7)}}{\text{Column (6)}}$; Column (10) $= \frac{\text{Column (8)}}{\text{Column (9)}}$; Column (13) $= \frac{\text{Column (3)}}{\text{Column (11)} \times \text{Column (6)}}$; Column (17) $= \frac{\text{Column (16)}}{\text{Column (12)}}$; Column (18) $= \frac{\text{Column (16)}}{\text{Column (13)}}$; and, Column (20) $= \frac{\text{Column (19)}}{\text{Column (16)}}$.

* *Reclamation Record*, December, 1923, p. 314, and August, 1923, p. 274.
† *New Reclamation Era*, February, 1926, p. 18.

Most crops start to grow when the mean monthly temperatures range from 42 to 48° Fahr., but the growth at the lower temperatures is slow and for that reason 50° Fahr. was selected as the base (see Fig. 1). The cumulative mean monthly temperatures were computed above that base and were called the growing temperatures.

In Fig. 1 the losses, crop values, etc., are plotted against the growing temperatures. The losses for the higher growing temperatures are very small, but, for the lower temperatures, they are an appreciable item. The rate of increase in irrigable acreage is also very much greater for the higher than for the lower growing temperatures.

The major item, however, is the larger acreage crop values and the relatively greater increase in crop values in recent years when most agricultural products were suffering the decrease in value that accompanies the higher growing temperatures. Special crop conditions in the cold districts may produce the same effects as the higher growing temperatures.

The percentage of financial losses does not seem to be much when the annual gross acreage crop values are 50%, or more, of the acreage construction costs, but on projects costing three or more times the crop value the percentage of loss seems to increase as does the relative cost (see Fig. 2).

RHODES E. RULE,* ASSOC. M. AM. SOC. C. E. (by letter).†—It is indeed unfortunate that the history of irrigation in the United States is marked by so many financial disasters. The fact that "26% of all irrigation districts organized have failed in some period of their development"‡ is evidence that these projects have been undertaken with an enthusiasm blind to economic considerations.

The percentage is not so great compared to the failures in private enterprises, such as banks and industrial projects, but, unfortunately, the losses in the majority of these projects have been incurred by the purchasers of district bonds rather than by the enthusiastic promoters.

In California, the early history of irrigation district enterprises was so replete with financial failures that many bankers and financiers of the old school have built up a resistance to projects of this character that has worked a great hardship on even the most promising and substantial of the more recently formed districts, developed under the most rigid and intelligent State supervision. In districts having most favorable conditions of water supply, soil, climate, transportation, and demand for lands by legitimate settlers the bonds have had to be sold at discounts which have made the actual interest rates paid by the districts as high as 7 or 8 per cent. Nevertheless, despite the difficulties of financing and the high interest rates that these districts have been forced to pay there has been a tremendous expansion of the irrigated areas in California almost entirely under the irrigation district method. Between 1912 and 1926, one hundred irrigation districts were formed with a total bonded debt of $120 000 000. The total area involved was 3 500 000 acres, which is greater

* Civ. Engr. (Rule & Rule), San Diego, Calif.
† Received by the Secretary, August 23, 1929.
‡ *Proceedings*, Am. Soc. C. E., May, 1929, Papers and Discussions, p. 1197.

than all the Federal projects combined. These districts have met their financial obligations as they came due in almost every instance.

The reasons for the success of these projects can be summarized into the following items: (1) Adequate water supply; (2) favorable climate; (3) good soils; (4) good marketing conditions; and (5) a bonded debt within the ability of the district to pay.

Before an irrigation district can issue bonds the California Bond Certification Commission, consisting of the State Engineer, the Attorney General, and the State Superintendent of Banks, makes a comprehensive investigation to assure that the district meets these five conditions. The result has been that all the districts have had, to a greater or less degree, the one vital characteristic necessary to the success of any irrigation project—attractiveness to the adequately financed, intelligent, industrious farmer.

In comparison with reclamation projects in the interior arid States, projects in California have two environmental advantages, namely, an equable climate and proximity to great population centers and their attendant cultural advantages. These are of utmost importance in considering the colonization feature of a project. In determining the feasibility of a project that lacks these features the other conditions must be so favorable that they offset the disadvantages of an intensely hot climate and remoteness from large cities. The opportunity for financial gain must be greater than that in a more pleasing environment. For this reason, conditions for marketing agricultural products must be exceptionally good to induce settlers to take up land in the reclamation projects of the desert region.

That settlers will suffer unpleasant environmental conditions in order to take advantage of the opportunity of large profits is demonstrated by experiment in the Imperial Valley. In a period of twenty-nine years, this region has been converted from a forbidding desert into one of the most productive and richest agricultural sections in the country, with a population of 60 000 on an irrigated area of 525 000 acres. This growth has been made without subsidies of any kind.

It is probable that many of the Reclamation Service projects that have been in difficulty would have been more successful if a somewhat different policy had been adopted. A settler entering upon the raw land has a great and sometimes hopeless task confronting him. The preparation of land for irrigation, building of home and barns, purchase of farming equipment and stock, learning new methods of farming necessary under local conditions, building of roads, schools, churches, and all the service utilities necessary to a prosperous community, all require capital, intelligence, and an indomitable courage that the average land seeker does not possess. Unfortunately, too many of the settlers on reclamation projects are those who have failed in their previous endeavors and are seeking new opportunities in a new land. In most cases the causes of their original failures are still present in their new environment and they either abandon their efforts or hold on by a thread without contributing any support toward building up the wealth of the community. The burden of development is on the few industrious and, in most cases, adequately

financed pioneers who understand farming and are fully aware of all the difficulties that must be overcome.

If conditions were such that a larger number of the latter type could be attracted to settle on the land, development would be more rapid and failures fewer. If the amount of original capital required for a settler to establish land on an earning basis were less, a larger number of settlers of the right type would be attracted to it. This might be accomplished by including in the project construction some things that now are accomplished by the expenditure of cash or labor on the part of the settler. As Mr. Mead* suggests, this might include leveling of land and the construction of roads. Community buildings and utilities might also be included in some instances. Any steps along these lines should be taken with caution and after due consideration of all factors. A small scale experiment should be instituted before great expenditures of the public money are made. The experiences of some Utopian colonization schemes should not be forgotten.

As suggested by the Committee,† subsidy by the Government should take the form of an assumption of a part of the total cost of the project rather than aid to the individual farmer. Local subsidy should be largely of a similar nature. Regarding the latter, there is no question in the writer's mind that, in many instances, such measures are justified. The development of new agricultural areas creates wealth and affords means of livelihood for the inhabitants of the towns and cities. That a State or county is justified in lending aid to reclamation projects within its limits cannot be denied. Another form of assessment against those indirectly benefited is the inclusion, within an irrigation district, of cities and towns lying within the irrigated area and the taxing of these lands by the district to pay the interest and principal on a part of the bonded debt. In many cases these cities and towns would not exist if it were not for the irrigation projects and virtually all business in them can be traced indirectly to the agricultural back country. Surely a part of the cost of the project should be borne by these lands.

GEORGE M. BACON,‡ M. AM. SOC. C. E. (by letter).§—There seems to be a tendency to regard the report on a National reclamation policy as inimical to the U. S. Bureau of Reclamation. It would be very unfortunate if implications were read into this report which did not really exist.

The supplementary remarks‖ by Mr. Mead comprise a well-reasoned argument for aid by the Bureau of Reclamation to the prospective settler on present and future projects. As a general proposition there should be no quarrel over this; on the other hand, if the Bureau should take over this work—and it seems to be the proper agency—it would still form only a small part of that in which it can be rightfully engaged.

In the West, engineers are rather familiar with the conditions that have caused some of the projects to be, for the present at least, failures from a financial point of view. The fact of such failures is not vital and it would

* *Proceedings*, Am. Soc. C. E., May, 1929, Papers and Discussions, pp. 1209-1210.
† *Loc. cit.*, September, 1928, Papers and Discussions, p. 2097.
‡ State Engr., Salt Lake City, Utah.
§ Received by the Secretary, August 26, 1929.
‖ *Proceedings*, Am. Soc. C. E., May, 1929, Papers and Discussions, p. 1193.

be difficult to find any enterprise involving the expenditure of $125 000 000 in which mistakes of considerable size were not made. The immediate and proper question is the avoidance of similar mistakes in the future and there is much doubt in the minds of the Committee whether such steps are being taken.

The fundamental idea in setting up the Reclamation Fund was that it should be a revolving fund and that expenditures from it should be repaid. This idea has been departed from to the extent of at least $14 000 000, according to Mr. Mead's figures,* and there is no question as to this being an entering wedge for further departures. There are many who argue that the indirect benefits derived from construction of the various projects more than outweigh the losses, but it seems to the writer that this argument does not go to the root of the situation. If the construction of projects which do not pay is to be gone into for their indirect benefits, it should be definitely understood before the project is started. It may possibly be that the funds for Federal reclamation should be spent for indirect benefits, but it is obvious that any policy of that kind, or tendency in that direction, is extremely dangerous. Should it be tolerated it would mean that projects were built for sentimental reasons, or on account of political pressure, and it might be pointed out that the pressure for the construction of the various projects almost never comes from those who have to pay the bill. The prominent advocates of new projects to bring in raw land will be found to be, not the farmer, but various urban interests and organizations.

The Committee sought to stage† lines upon which the work of the Bureau might be continued with benefit to all, keeping within the fundamental limits set by the establishment of a revolving fund, and that its report seemed to be critical as to some of the work done by the Bureau should not be misunderstood.

It should be noted that for years the Bureau has been limited to a large degree in its choice of projects. The law now requires a specific appropriation by the Congress for the various projects and most people know how appropriations are usually obtained. The writer feels that the Bureau could be safely trusted to pass on the economic merits of a proposed project and, with the understanding that a project must pay, limit the construction of new projects to such as are economically feasible. There is no question in the minds of engineers competent to judge that at least two projects are being constructed at the present time which will not pay in this sense and others of this nature are not far distant.

The danger of Mr. Mead's plea‡ for help to the prospective settler is that new projects which will not pay, may be started with a tacit understanding that, if anything does happen, a considerable portion of the cost will be written off and then various aids will be offered to prospective settlers. Following this line of procedure one step further, the day may come when the money furnished to aid the settler need not be wholly repaid and then the argument can again be advanced that the indirect benefits warrant such a course.

* *Proceedings*, Am. Soc. C. E., May, 1929, Papers and Discussions, p. 1194.
† *Loc. cit.*, September, 1928, Papers and Discussions, p. 2897.
‡ *Loc. cit.*, May, 1929, Papers and Discussions, p. 1209.

There are signs of a growing belief among careful students that from now on history, as to growth of total population, or rural population, will not repeat itself in this country. It is even believed that the total agricultural area under cultivation at present is ample to provide for the needs of the country for a long time. Speaking of the arid and semi-arid West there is no question at all that the total area under cultivation is capable of great increase in produce once its present water supply is supplemented. There are many thousands of acres of land on which production is curtailed because the water supply falls short before the end of the crop season.

The policy in all ordinary business is to bring the plant up to full capacity before enlargement but, as far as agriculture is concerned, the exact opposite has been, and still is, strongly advocated. It is very difficult to realize the unconscious pressure which is being exerted all the time in favor of an increase in agricultural area; and it is still more difficult to realize how little of this pressure comes from the man who is supposed to come on to this new acreage, pioneer to a large extent, make a living, if possible, and then pay for the cost of the project.

Many people draw an analogy from the industrial field and point out how products in an industrial line are absorbed beyond any forecast which has been made. They seldom stop to think that as far as staple food products are concerned there is a definite limit beyond which it is impossible to go after people are well fed. The analogy does hold in part in the case of what a few years ago were considered food luxuries and, as the standards of living become higher, the power to absorb such luxuries will increase. As to these luxuries, it will undoubtedly be many years hence before anything like what might be termed a saturation point is reached.

The picture that Mr. Mead paints is accurate and important, but the point to be borne in mind is that this is by no means the whole picture. As he intimates, one kind of picture would be drawn by engineers, another by the settler, another by the economist, and probably another by the politician. The consideration of vital importance is that these pictures fit into the frame of the law as laid down by the Congress of the United States; if they do not, they cannot be regarded as a fair presentation. Many of the policies advocated by the enthusiastic friends of Federal reclamation are good in themselves but, as long as they have to be paid for by money which is supposed to be repaid, there should be a definite understanding that a business transaction is involved and that obligations to be undertaken are as binding between the Government and individuals as between private parties.

AMERICAN SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

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SPECIFICATIONS FOR TRANSIT TRAVERSING AND STADIA LEVELING

Discussion*

By W. H. Rayner, Assoc. M. Am. Soc. C. E.†

W. H. Rayner,‡ Assoc. M. Am. Soc. C. E. (by letter).§—In the discussion‖ of this paper, exception is taken to the assumption that an error is a quantity of which both the magnitude and the sign are unknown; and also to the corresponding definitions of "systematic error" and "cumulate".

It has seemed to the writer that there always has been an element of confusion in the discussion of the subject of errors because the term, "error", has included both the significant and the non-significant quantities which constitute the difference between any measured value and the corresponding true value. In the paper¶ the significant and non-significant quantities were defined as "error" and "cumulate", respectively.

The analogy is not complete, but there is a similarity between the terms, "cumulate", as used in this discussion, and "tare", as used in weights. To weigh certain commodities a "gross" and a "tare" weight are taken, from which the "net" weight is obtained. The tare is sometimes found by weighing a container and sometimes it is compensated for, by a counterpoise. Thus, the tare weight may be found by a computation (that is, a correction), or it may be eliminated by a systematic procedure. The term, "error", as it has been commonly used, may be said to correspond to a "gross" measurement, including both the significant ("net" corresponding to "error") and the non-significant ("tare", corresponding to "cumulate") quantities.

If the proposed meaning of the term, "error", is accepted; namely, that it is that part of the difference between a true and a measured quantity which remains after the cumulate has been removed, then it is believed that the definition of the term "systematic error" as stated,¶ is correct.

* Discussion of the paper by W. H. Rayner, Assoc. M. Am. Soc. C. E., continued from April, 1929, *Proceedings*.

† Author's closure.

‡ Asst. Prof. of Surveying, Univ. of Illinois, Urbana, Ill.

§ Received by the Secretary, August 22, 1929.

‖ *Proceedings*, Am. Soc. C. E., April, 1929, Papers and Discussions, p. 1056.

¶ *Loc. cit.*, December, 1928, Papers and Discussions, p. 2640.

In the discussion it has been stated* that,

"That part of the definition relating to the sign does not seem to be correct or essential, because the error due to the wind effect of a suspended tape is always such as to make the measured length too large, as is also the error due to lack of alignment of a tape. Other examples of the same tenor could be cited."

Mr. Rappleye† also uses the same example and the additional one that "the error due to phase in pointing on a signal is certainly systematic, but its sign is not necessarily unknown."

In both these statements the sign of the "gross" error is known; but if so, would it not be logical to make an estimated or calculated correction? Thus, the effect of the wind on the tape may be estimated and the correction subtracted from the measured length. After this estimated correction has been applied (that is, after the cumulate has been removed) one cannot then say whether the remaining error is plus or minus, because the estimated correction may have been too large or too small. Similarly, after a correction for phase in sighting a signal has been applied, one cannot say what the sign of the remaining error will be. In passing, it may be stated that the distinction between the terms, "cumulate" and "correction", is that they have opposite signs. The cumulate is the quantity that is removed by applying the corresponding correction. However, probably little harm is done in using the terms interchangeably.

Mr. Rappleye further questions† that part of the writer's definition‡ of a systematic error which states that "its effect cannot be removed by systematic field methods". He uses the example of a forward chainman who has a tendency to mark to the right of the end of the tape, the effect of which is eliminated by the process used in measuring forward and back.

Here, again, he is using the term, "error", in its customary meaning and not according to that proposed. To the extent that the effect of measuring to the right is eliminated by a systematic field procedure it is non-significant and has been rendered a cumulate. In this instance the "tare" quantity has been obtained, not by a calculation but by a "counterpoise", that is, a systematic procedure. Surely it must be admitted that a final error remains, due to the effect under consideration. This remaining error, however small, is the significant or true error, and one cannot say what its sign or magnitude is.

The writer agrees that a "systematic error"* need not always have the same sign. Of course, such conditions as temperature, direction of the wind and of the sun's rays, change from time to time; but any one of these conditions causes a systematic error only under the condition that its effect has the same sign for a considerable number of consecutive observations. Accordingly, the definition is improved by omitting the word "always", making it read "an error which has the same (unknown) sign, etc."

It may be added that the discussion of the definitions of the terms used is, after all, of little importance as compared with the major proposal with which the paper deals.

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* *Proceedings*, Am. Soc. C. E., April, 1929, Papers and Discussions, p. 1056.

† *Loc. cit.*, p. 1061.

‡ *Loc. cit.*, December, 1928, Papers and Discussions, p. 2640.

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PAPERS AND DISCUSSIONS

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COMMENTS ON THE DESIGN OF SLUDGE DIGESTION TANKS

Discussion*

BY RICHARD H. GOULD, M. AM. SOC. C. E.†

RICHARD H. GOULD,‡ M. AM. SOC. C. E. (by letter).§—Discussions oftentimes contribute material and thoughts more valuable than the original paper. From the writer's standpoint, the discussions submitted in this case certainly are most interesting and instructive.

The comments on the paper‖ come from engineers representing the interests that are bringing about the noteworthy advances in the art of sewage disposal. The discussion includes remarks by consulting and sanitary engineers, a research investigator, an experienced plant operator, and a representative from a firm supplying appliances used in sewage disposal. It is gratifying to realize that the improvements in sewage disposal methods are being followed so closely by people representing so many different points of view, and to know how each group recognizes its dependence one upon the other.

Mr. Eddy¶ has traced the development of sewage disposal, and has pointed out the trend toward more elaborate and costly plants. He has described certain of the difficulties that this trend involves. Many of the plants now being constructed require highly technical supervision in their operation. The fact that it is difficult at present to secure operators with adequate training may perhaps be classified as a "growing pain" which may soon be overcome. The various sewage works associations, with the co-operation of some of the State boards of health and the educational institutions, are now making determined efforts to increase the technical knowledge and ability of sewage plant operators. Mr. Donohue** makes the argument in this connection, that if equip-

* Discussion of the paper by Richard H. Gould, M. Am. Soc. C. E., continued from August, 1929, *Proceedings*.

† Author's closure.

‡ Chf. Engr., Ward's Island Sewage Treatment Works, New York, N. Y.

§ Received by the Secretary, August 16, 1929.

‖ *Proceedings*, Am. Soc. C. E., December, 1928, Papers and Discussions, p. 2655.

¶ *Loc. cit.*, April, 1929, Papers and Discussions, p. 1063.

** *Loc. cit.*, p. 1076.

ment requiring expert supervision is installed, the necessary supervision will be supplied and the operation of the plant as a whole will benefit thereby.

It is to be expected that the cost of disposal works will be higher than was formerly necessary. In many cases the necessity for sewage disposal depends on the concentration of population, where means for the assimilation of sewage in the natural bodies of water are limited. The increase of population creates increased land values and may make it impossible to secure isolated sites, where some of the cruder methods of disposal might be practiced. The trend is, therefore, toward the construction of plants on a limited area capable of bringing about a high degree of purification, and doing this without the production of objectionable odors that will lower adjacent property values.

The demands made in many cases require a more or less complicated plant, and the amounts invested certainly warrant highly trained technical supervision. It would be false economy indeed, to withhold proper compensation for such service. After all, the fact that complete disposal of sewage can usually be secured at a cost of about $1 or $2 per capita per year, permits little criticism of such an expenditure for so important a necessity.

The discussions by Mr. Besselievre* and Mr. Allen† bring out some of the differences of opinion that are common in sewage disposal practice. Mr. Allen thinks there may be some advantage in digestion in separate stages, and points out the disadvantage of mechanical stirring, in that some of the fresher sludge is discharged with the more thoroughly digested material. It seems that more data are necessary to establish definitely the fact that there are practical advantages in several separate digestion stages.

The action in a digestion tank, as described by Dr. Rudolfs,‡ where the solids in a state of gassification are constantly rising and falling, depending on whether or not bubbles of gas are attached to the particles, does, in effect, tend to separate the digestion processes to a certain extent; that is, the particles undergoing active gassification tend to remain in the upper part of the tank, while those which have become inert work their way toward the bottom.

It would be interesting to compare the effectiveness of the gentle stirring caused by a mechanical contrivance, with the stirring action of these rising gases of digestion. It will be recalled that many years ago, Dr. Imhoff used this argument among others, in advocating the use of deep tanks, when, as in this case, there would be better stirring action owing to the increased amount of gas produced per square foot of area.

The speculation of engineers, the researches of scientists, and the mechanical ingenuity of manufacturers are extremely valuable; but, after all, the results secured in operation are the most important. So it is that concrete results of operation, such as that given by Mr. Downes,‡ are especially welcome

* *Proceedings*, Am. Soc. C. E., April, 1929, Papers and Discussions, p. 1069.
† *Loc. cit.*, August, 1929, Papers and Discussions, p. 1639.
‡ *Loc. cit.*, April, 1929, Papers and Discussions, p. 1065.

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PAPERS AND DISCUSSIONS

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EXPERIMENTS ON DISCHARGE OVER SPILLWAYS AND MODELS, KEOKUK DAM

Discussion*

By B. F. Groat, M. Am. Soc. C. E.

B. F. Groat,† M. Am. Soc. C. E. (by letter).‡—It is doubtful whether most engineers can appreciate the difficulties of real pioneer investigation. Most of the great works of engineering were erected from plans based on well-tried methods—"accepted practice". This is eminently proper, because lives and dollars should not be subjected to unnecessary risk by structures built on sands of misapplied theory. Nevertheless, spillway discharge has been for years a subject of more, rather than less, speculation as to just what the coefficient should be, especially for high heads. In this paper the authors have joined hands in a real pioneer investigation, the difficulties of which will be fully realized by all engineers who have had opportunity to conduct such researches.

The conditions surrounding experimental work are so complicated and interwoven in relationships that it is often necessary to expend a great amount of time, labor, and experimental mechanism, before any useful result can be obtained. Sometimes, an apparently simple device will be used for years before its unreliability is fully and generally suspected. This was the case with current meters when used for precise water measurements. One of the first, if not the first, to notice the effect of turbulent flow in causing a change of current-meter ratings was the late Charles H. Miller, M. Am. Soc. C. E.§

Notwithstanding the many criticisms made by later observers, the current meter is to-day frequently used by engineers without regard to Miller's words of caution. It is, therefore, a source of satisfaction to know that the careful experimenters at Keokuk have applied corrections for errors due to angular disposition of the meters. The writer has also made similar efforts to correct the errors of current meters.

* Discussion of the paper by Floyd A. Nagler and Albion Davis, Members, Am. Soc. C. E., continued from September, 1929, *Proceedings*.

† Cons. Engr., Brookline, Mass.

‡ Received by the Secretary, June 21, 1929.

§ *Engineering News*, January 24, 1895, p. 58; also, "The Discharge of the Mississippi River," by William Starling, M. Am. Soc. C. E., *Transactions*, Vol. XXXIV (1895), p. 367.

In one extensive series of experiments the discharge of large turbines at Massena, N. Y., was measured simultaneously by current meters and chemicals. These comparisons were from the earlier and least accurate of the chemical tests, but, even in these, the results show a high degree of precision in both methods of measurement.* Omitting three tests in which there were known faults in the laboratory, or apparatus, the results were as given in Table 10.

TABLE 10.—Comparisons of Discharge Measurements.

Test No.	Discharge Determined by:	
	Current meter, in cubic feet per second.	Chemical method, in cubic feet per second.
G	1 663	1 662
H	1 662	1 662
I	1 662	1 666
K	1 618	1 683
L	1 648	1 647
N	1 785	1 777
O	1 783	1 768
S	1 676	1 640
Total	13 497	13 505

The current meters used in these tests consisted of three different types, namely, one small Price meter, two Haskell meters, and two Ott meters. They operated on a movable frame, so that, by shifting once at each elevation, the five meters gave records for ten different points of observation in the cross-section. As there were ten elevations at which the meters operated, there were, in all, 100 velocity readings for one complete sweep of the frame, which corresponds with one test.†

No such satisfactory agreement could possibly have been attained in these tests had the ratings of the meters not been carefully corrected for errors. This will be appreciated when it is stated that some of the meters (depending on their type and their position in the raceway) diverged from their true ratings by amounts varying from + 10 to — 25 per cent.

The meters were held rigidly with axes pointing up stream, parallel to the axis of the raceway in all cases. The writer is sure that a meter which is allowed to swivel about its support is not as reliable as one fixed in its position, ratings in both cases being corrected for turbulence. Moreover, since there is no meter that gives a correct resolved component of motion, engineers should always use at least two types of meter simultaneously. One of these should be a screw type and the other a cup, because the former is retarded and the latter accelerated. This is not to be considered a criticism of the method of correcting ratings adopted by the authors, however, because the case in hand is rendered far simpler than in one in which there is great turbulence, as shown by the statement† that,

"The water being accelerated as it passed over the crest, flowed with remarkable uniformity in smooth stream lines and was free from the character-

* "Chemi-Hydrometry and the Precise Testing of Hydro-Electric Generators," *Transactions*, Am. Soc. C. E., Vol. LXXX (1916), p. 1270, Table 92.

† *Proceedings* Am. Soc. C. E., February, 1929, Papers and Discussions, p. 317.

istic pulsations in velocity and annoying vortices which so often accompany the phenomenon of flow in other channels."

However this may be, the writer believes he is perfectly correct in the following propositions which ought to be considered as theorems of hydraulics:

(1) Meters should be held rigidly.
(2) A "rudder", or "tail", is a monstrous absurdity.
(3) A "screw" type of meter can be designed to give the resolved component.

These statements are not directed toward manufacturers, but to engineers as a whole who take altogether too long a time to make the most of past experience. It is about 250 years since, in a single paragraph, Newton enunciated the principles of similarity and the theory of models, to which no man has been able to add one jot of additional theory; yet it is only in the last very few years that engineers have made any use of models as a reliable means for determining a design, especially in hydraulics. Charles Warren Hunt, M. Am. Soc. C. E., has stated* the fact very tersely as follows: "* * * a model is the only means for reproducing all the complexities of flow caused by natural channel conditions".

It is important to know how small the model may be made without loss of value as a reliable criterion. This is a question of special importance relative to experiments in which a long waterway is involved. In such cases the effects of friction are of much greater account than they are for weir, or spillway discharge, in which there is very little chance for frictional resistances, owing to the short length of the waterway involved.

As a matter of fact, the coefficient for frictionless weir discharge could not differ greatly from the coefficient determined by experiment, since the effect of friction is practically nothing for a weir. When the statement is made that the coefficient for frictionless flow would be about the same as for an experiment, it must be remembered that the equation, $Q = C\,L\,h^{\frac{3}{2}}$, is not a theoretical formula, but an empirical one. Therefore, the coefficient, C, for frictionless flow—instead of being unity—would express the numerical value of the function of H which would convert the empirical formula into the correct theoretical formula. That function, if correct in form, would undoubtedly eliminate H in terms of a true "head on the weir".

Before considering a weir and its model it will be desirable to acquire an understanding of the true nature of hydraulic friction. In the first place, there cannot possibly be any ordinary "sliding friction" of a fluid along the surface of a solid where there is contact. This theorem has been proved by many experimenters, notably first by Poiseuille in his celebrated experiments on the flow of fluids through capillary tubes. In cases of turbulent flow the velocity a short distance from the surface may be relatively high; but the presence of the "film" is certain, although its thickness may be very slight. The thickness of the film depends on the neighboring velocity of the fluid, the fluid itself, and the character and condition of the surface.

* *Transactions*, Am. Soc. C. E., Vol. LXXXII (1918), p. 1168.

It is this thinning of the film (due to motion near-by) of steam, water, or air, along the side of a radiator which increases the heat conductivity of the radiator enormously. As a matter of established fact, the great resistance to heat transmission through good conductors is due principally to the thermal resistances of the fluid films on the two sides of the conductor, rather than to the resistances of the conductors themselves. For example, water boils only a little more quickly in a thin metal pot than in one of the same material several times thicker, or than in one made of thin asbestos, say. Asbestos is a poor conductor as regards the flow of heat through its material, but, for a thin sheet of asbestos, the resistance of its material is much less than the resistances of the fluid films on the two sides, even if the water be in turbulent motion. No correct estimate of heat conduction through walls from one medium to another can be made unless the films of the media on the walls of the conductor be taken into account. In many cases, the resistances of the conducting materials themselves can actually be omitted without serious error.

The film of water along the wall of a channel (or pipe) is not at rest, except along the surface of contact, even if the thickness is extremely slight. There is undoubtedly motion at an indefinitely short distance from the wall. The experiments in heating and hydraulics have both shown that films are thicker with lesser velocities, and that with certain very small but determinate velocities the entire contents of the pipe acts precisely like the film along the wall. The whole becomes a mass flowing somewhat coheringly yet plastically as a thick liquid (molasses) flowing through and out of a pipe. This is the case of pure viscous flow in which there are no eddies at all. It is just a smooth, relatively slow flow, in which, however, there is a transverse velocity gradient, or the velocity increases from nothing at the walls to a maximum at the center.

This transverse velocity gradient, expressed by the ratio, $\frac{d\,v}{d\,x}$, simply specifies the relative amount of sliding (shearing motion) per second of two parallel lamina of uniformly moving water, at a distance, $d\,x$, apart. The law of viscous friction states that the total shearing resistance, F, between these two neighboring lamina is $\mu\,\frac{d\,v}{d\,x}\,A$, in which, μ is the coefficient of viscosity; A, the area of either of the two lamina (the area along which the shear occurs); and $d\,x$ is indefinitely small. Thus, the intensity of shearing stress is:

$$\frac{F}{A} = \mu\,\frac{d\,v}{d\,x} \qquad \ldots\ldots(1)$$

Concerning the flow in a long straight, horizontal, cylindrical pipe, consider a co-axial cylinder (variable radius, x) of water in the pipe. The cylinder of water is being thrust forward by the difference in the pressures upon the two ends of the pipe. Then, the intensity of the shearing stress set up along the convex area of the co-axial cylinder of water is the difference of the end pressures, divided by the convex area of cylinder, or:

$$\frac{F}{A} = \frac{p\,\pi\,x^2}{2\,\pi\,x\,l} = \frac{p\,x}{2\,l} \qquad \ldots\ldots(2)$$

Equating and integrating Equations (1) and (2): $-\mu \frac{dv}{dx} = \frac{px}{2l}$, $v_c = \frac{pr^2}{4\mu l}$, and $v = \frac{p(r^2 - x^2)}{4\mu l}$, in which, v_c is the velocity along the axis (central) and v is the velocity at distance, x, from the axis.

Then, the total discharge and mean velocity of the water through the pipe are, respectively,

$$Q = \pi \int v\,(2x\,dx) = \frac{\pi p r^4}{8\mu l} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

$$V = \frac{Q}{\pi r^2} = \frac{pr^2}{8\mu l} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

This analysis is substantially that given by Lamb* although it is less formal. Equation (3), thus established theoretically, is exactly that found experimentally by Poiseuille in 1840. Equation (4) demonstrates that the pressure drop is proportional to the velocity directly, and not to the square, for pure viscous flow.

The common idea seems to be that turbulent conditions have little to do with viscosity. Lamb states:†

"The resistance, in the case of turbulent flow, is found to be sensibly independent of the temperature, and, therefore, of the viscosity of the fluid. This is what we should anticipate from considerations of dimensions, if it be assumed that R varies as the square of the mean velocity relative to the wetted surface."

Lamb also quotes formulas for the coefficient of ordinary skin friction as given by Unwin.‡

Notwithstanding the opinions and statements of these profound authorities it is confidently submitted that all "frictional" resistance to flow is due, either directly or indirectly, to viscosity; and that if the viscosity of the water were zero, it would be a frictionless fluid in which there could be no such resistances. Of course, there would be resistance to velocity changes, but that would relate merely to "conserved" energy, available to support the flow and would not represent "lost work", as in the case of frictional resistances. Hydraulic friction is due entirely to viscosity acting under one, or both, of two regimens; that is, direct-shearing, or eddy-making and eddy-destroying.

How is it possible to pass from a "perfect" (frictionless) fluid to an actual ("viscous") fluid solely by introducing the character of viscosity, without having all frictional resistances dependent on the viscosity? If vortices could be generated in a perfect fluid at some definite relative rate, then energy would be absorbed by such eddies (that is, in their kinetic energy content) and lost work would result; but it is not apparent how such eddies could be generated in a perfect fluid, and it is very apparent that, if they were generated, there would be continually increasing turbulence progressing down stream, since a perfect fluid could not possibly dissipate any of its internal energy. Liquid

* "Hydrodynamics," Third Edition, 1906, p. 543.

† *Loc. cit.*, p. 593.

‡ An error in the value of the coefficient, u, of viscosity given in the Ninth Edition of the Encyclopædia Britannica, was pointed out by the writer in 1909 in a paper on "Back-Water," *Minnesota Engineer*, Univ. of Minnesota. This error was carried forward in the Eleventh Edition of the Encyclopædia, and was again pointed out in a paper on "The Pitot Tube and Chemical Gauging," *Proceedings*, Engrs. Soc. of Western Pennsylvania, May, 1914.

motion cannot be "killed" without internal viscous resistances. Otherwise, there is no such thing as "impact" (of fluid upon fluid) in a fluid. Neither can there be impact upon a solid by a liquid in the sense that energy is destroyed by that impact. In every case it must be the property of viscosity which ultimately converts waste motion into heat. In fact, it seems only reasonable to conclude that the whole configuration and character of the eddy system is dependent to a great extent on viscosity, although, of course, the shape and character of the flow and boundaries of the flow must have also a very great influence on the delivery of kinetic energy to the re-acting viscous resistances.

Consider now the turbulent flow of a river. The channel may be assumed to be uniform in section, that is, of a generally prismatic nature; but the wet perimeter is more or less undulatory and "rough". These undulations deflect water from the bottom and project it into the body of the stream, at greater or less velocity. The projected disturbances do not occur as definite streams of water, but as erratic pulsations, eddies, "boilers", and open vortices.

In such a stream, a large deeply floating body, such as a ship, may float down stream either faster or slower (but usually faster), than the mean velocity of the water with which the body is in contact, depending on the distribution of velocities in the stream, the slope of the water surface, and the position, size, shape, and depth of flotation of the body.

In this connection Francis quotes Weisbach as follows: "As a rule * * * the velocity of a swimming body is somewhat greater than the water". This was illustrated in an extensive study of the rod float, made by the writer, which is as yet unpublished.

Incidentally, the rod float is an excellent instrument for the measurement of the mean velocity of flowing water. It has been practically discarded by the profession, despite the fact that it is much more reliable and much simpler, for many purposes (even for refined work) than current meters, especially for gauging flow in canals of prismatic section. This simplification is made possible by the rod-float tables computed during the study.

It is important to note that the late J. P. Frizell, M. Am. Soc. C. E., actually calculated the theoretical velocity from that of a rod float for one condition of flow and depth of immersion. Francis distracted his attention, however, by showing that a float tended to slide down the inclined surface of the water and by stating that he thought it best to use empirical methods. Had it not been for this situation, Frizell would probably have solved the rod-float problem completely.

Theorem 1.—If the greater velocities (of an enveloping layer of water around a floating body, as a ship, or rod float) have the greater weights (averaging weights), and impulsive forces (due to skin friction) are proportional to the squares of impinging velocities, the velocity of the floating body is less than the mean velocity of the enveloping layer of water; but if the smaller velocities have the greater weights, the velocity of the floating body exceeds the mean velocity of the enveloping layer.

When the writer first demonstrated this theorem he was apparently squarely against Weisbach's statement that a ship would float down stream more rapidly

than the current, because the theorem shows that a rod float will tend to move less rapidly than the water with which it is in contact. Nevertheless, as may be clearly seen, an application of the theorem to the two cases, taking into account the vertical velocity curve of the river (generally concave up streamward), and the size, shape, and position of the floating body, brings all into harmony. If the law of skin friction relates to the first power of the impinging velocity only, then the floating body moves exactly with the mean velocity of the enveloping layer.

This theorem is independent of the tendency of the floating body to slide down the slope of the water surface, but another theorem shows that this tendency is generally of lesser importance.

Theorem 2.—If a body floats in a uniform current, and an independent propelling force acts upon that body in the line of action of the force due to hydraulic slope, then the total change, x, in velocity, from the condition in which the propelling force acts alone, to that in which the two forces combine, is less than the velocity which the hydraulic slope alone would produce, except the one case in which the propelling force is directed up stream and does not exceed the force due to slope.

The theorem does not except the case when the propelling force is directed up stream and exceeds the force due to slope. When the two forces are equal and opposed the change in velocity is, of course, just equal to the velocity due to slope.

The theorem is illustrated by the fact that a relatively small force will tow a large vessel in still water at a rate of several miles per hour, when the application of that same force in the line of motion when the vessel is being driven at full speed by its own power, would have scarcely any appreciable effect toward increasing, or decreasing, the speed. The theorem shows that the effect of slope is much diminished in the currents of rivers and canals, as against the action of slope in uniformly flowing water, because, in the latter case, there would be no independent propelling force.

These theorems are very important, because they have an illuminating relation to the questions of turbulent flow of rivers. Suppose, for example, a large mass of water is flowing down stream as a unit, with practically uniform velocity. The theory shows that it will tend to flow either faster, or slower, than the mean velocity of the water with which it is in contact. This would mean the generation of eddies and "boilers" around, and finally within, the body of water, so that there would be "internal" frictional losses within the body of water flowing in a stream due to the generation of turbulence internally.

This completes the picture of turbulent flow; it shows that these internal turbulent resistances may still be assumed to result from the effect of the bottom, or wet perimeter, because the variations of velocity must be due ultimately to disturbances emanating at and along the wetted surface.

To analyze this condition assume that the agitating area is the wet surface, measured by $P\,l$, in which, P is the perimeter of the cross-section, and l is the length of, or uniform reach of, the river. The volume of the water agitated along the wet surface is $n\,P\,l\,v$, in which, n is a dimensionless coefficient depending on the shape and character of the bottom, and v is the mean effective

velocity with which the water is deflected from the agitating wet surface. If V is the actual mean velocity in the section, and A is the cross-sectional area:

$$n\,P\,l\,v = n\,\frac{P\,l\,v}{A\,V}\,Q = n\left(\frac{v}{V}\right)\frac{l}{m}\,Q \quad \ldots\ldots\ldots\ldots\ldots (5)$$

since $\frac{P}{A} = \frac{1}{m}$, $Q = A\,V$ is the rate of discharge, and m is the hydraulic mean depth.

This volume of water deflected from the sides with effective velocity, v, has the kinetic energy,

$$\frac{n\,l\,v}{2\,m\,V}\,Q\,\delta\,v^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

All this is finally converted into heat by viscous resistances within the resulting eddies and the turbulence. It becomes lost as kinetic energy of the flow. The resulting loss of head is the loss of energy per pound of water discharged (total discharge); that is,

$$h = \frac{n\,v\,l}{2\,V\,m}\,\frac{Q\,\delta\,v^2}{w\,Q} = n\left(\frac{v}{V}\right)^3\frac{l\,v^2}{m\,2\,g} \quad \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Substituting for the quantity, $n\,\frac{v^3}{V^3}$, the factor, f, which is the dimensionless coefficient of loss due to turbulence, Equation (7) becomes:

$$h = f\,\frac{l}{m}\,\frac{V^2}{2\,g} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

The ratio, $\frac{v}{V}$, denotes the ratio of the effective velocity of projection from the bottom to the mean velocity of flow in the river. Its value depends on the shape, dimensions, and other characteristics of the channel. The channel may be that of a pipe, but in that case f would be different. The reason such a dimensionless ratio can be merged with a dimensionless coefficient so as to form a modified coefficient, is that the mean velocity (as to time) at any given point in a river, in the case of steady flow, bears a constant ratio to the mean velocity of the river flow. This is a condition practically maintained in actual streams as regards mean point velocities in the cross-section, and this proposition is here extended to apply to the average pulsations in disturbances emanating from the wet area. Of course, the ratios change with change of stage, but, then, the dimensionless coefficients change also, so that no new character is attributed to the coefficients by the consolidation.

Observe carefully that Equation (8) is a rigorous theoretical formula except that, as yet, no method is shown for calculating the value of f. However, since the formula is the same as that used for years, values for f are available, based on a great amount of experience. As f is dimensionless, it has the same value in all systems of units, for any given channel. Observe, also, that the formula involves the exact square of the velocity, in so far as it relates to the losses of head resulting from pure turbulence. It is quite wrong to state that the loss due to turbulence (pure turbulence) varies in any other manner than as the exact square of the velocity (the mean velocity) in the

cross-section. This is true, because all the velocities to which lost kinetic energy is to be assigned vary as the mean velocity in the cross-section, referring, of course, in each instance, to time averages for properly determined periods.

This discussion has treated separately the two cases—pure viscous flow and pure turbulent flow—each resulting in internal, as well as superficial losses along the wetted perimeter, the energy being dissipated in the form of heat. It is easy to understand that, along the boundaries in slowly moving pools as well as in the border films of turbulent flows, there must be more or less viscous resistance directed against the general flow. There must also be many places in the fluid where shearing resistances occur to check the flow, as it were. Thus, the total loss of head in friction is due to both causes acting simultaneously. Hence it is possible to add the two friction heads calculated in Equations (4) and (8). Since the pressure head of Equation (4) is $\frac{p}{w}$ (w being the specific weight of water):

$$h' = \frac{8\,\mu\,l\,V}{w\,r^2} = \frac{2\,\nu\,l\,V}{g\,m^2} = \frac{4\,\nu\,l\,V^2}{m\,V\,m\,2\,g} \quad \ldots\ldots\ldots\ldots\ldots\ldots (9)$$

in which, h' is used to distinguish any directly effective viscosity resistances that may occur simultaneously with turbulent flow, but not including those viscous resistances which dissipate the turbulent energy by subduing it, so to speak.

Equation (9), however, is not yet fully adapted to be applicable simultaneously with turbulent flow. The velocity in Equation (9) was defined as that due to pure viscous flow. Hence, as in the case of the coefficient in Equation (8), to apply Equation (9) to the case in which both turbulent and viscous resistances act together, it is necessary to introduce a friction factor, f'. Thus, combining Equations (4) and (8):

$$H^* = h' + h = \left(f' \frac{4\,\nu}{m\,V} + f\right) \frac{l\,V^2}{m\,2\,g} \quad \ldots\ldots\ldots\ldots\ldots\ldots (10)$$

which is a perfectly sound formula for the flow of water in any channel. The ratio of pure stream-line velocity (which would be determined by Equation (4)) to the actual mean velocity was assumed to be absorbed in the coefficient, f', just as the ratio, $\frac{v^3}{V^3}$, was absorbed in f, in Equation (8).

Of course, f is not the same in Equation (10) as the usual friction factor. In Equation (10) both f' and f are dimensionless friction factors. They depend on the kinematical coefficient, ν, of viscosity; the mean velocity in the cross-section; the roughness of perimeter, including curvature; and the dimensionless ratios of channel dimensions, such as $\frac{l}{m}$, $\frac{l}{P}$, and $\frac{\varepsilon}{m}$, in which, ε is some linear measure of relative roughness; l, the length of reach; m, the hydraulic radius; and P, the bounding wet perimeter of cross-section.

In pure viscous flow, $f = 0$. In the case of turbulent flow the writer would not expect to find that f' has negligible values. In fact, it is perfectly clear that it cannot have such values, since it is well known in hydraulic experi-

* Forms for F in terms of definite negative fractional exponents of Reynold's number relate to only one condition of roughness and one shape of channel boundary.

ence that resistances in turbulent flow vary as a power of the velocity less than the square. When turbulence exists the coefficient of friction becomes:

$$F = f' \frac{4\,\nu}{m\,V} + f \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (11)$$

and,

$$H^* = F \frac{l}{m} \frac{V^2}{2\,g} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (12)$$

It is clear from the value of F (which involves V in the denominator of one term) that H depends on a power of V less than the square, as is well known, but that there is no fixed relation of this kind applicable to all channels alike, and no fixed value for the exponent, even in the case of a given channel, although approximations have been made.* Equation (11) precludes the possibility of higher powers of V than the square, although, under extraordinary conditions, erroneous results may be obtained.

The correct solution of Equation (10) for the velocity is:

$$V = -\left(\phi \frac{\nu}{m}\right) + \sqrt{\left(\phi \frac{\nu}{m}\right)^2 + \left(\frac{m}{f\,l}\right)(2\,g\,H)} \quad \ldots\ldots\ldots (13)$$

in which, $\phi = \left(2 \frac{f'}{f}\right)$. The coefficients have been recast to adapt them to the form for the value of V.

Formulas of the general type of Equations (10) and (11), but without explicit mention of viscosity, have been proposed by eminent writers in the past.† Biel's formula takes into account the viscosity, but strict regard for dimensional form does not seem to have been followed, the idea apparently having been mainly to include two terms in metric units, one term in V, the other in V^2.

The idea of introducing ϕ in Equation (13) is to avoid obvious unnecessary mathematical difficulties by regarding ϕ and f as the only necessary coefficients. It should be noticed, however, that the coefficients of Equations (10) and (11) are properly the ones to be determined by experiment; but, for most practical purposes, the great amount of data available concerning the coefficient, F, in Equation (11), is quite sufficient.

Equation (13) includes Reynolds' critical velocity. When that occurs, f suddenly vanishes. By inserting the value of ϕ $\left(\text{that is, } \frac{2\,f'}{f}\right)$, it may be shown that Equation (13) reverts to Equation (9) for pure viscous flow. The velocity does not become infinite, as with some formulas.

The object of this discussion of hydraulic friction is not intended so much to adduce a new form of coefficient in terms of viscosity and turbulence, as to offer the true explanation of hydraulic resistance in channels of any kind, including weirs. The proposition that all hydraulic resistance depends ultimately on viscosity, so that, if this property were wanting, there would be no

* Forms for F in terms of definite negative fractional exponents of Reynold's number relate to only one condition of roughness and one shape of channel boundary.

† In 1909, the writer gave an account of Biel's formula in the *Minnesota Engineer*, Univ. of Minnesota, January, 1909.

hydraulic resistance (lost work), is bound to meet with some incredulity, until those who think that turbulence resistance is independent of viscosity give the question careful investigation. The writer here takes the anomalous position that there can be no turbulence without viscosity; yet viscosity tends to suppress the initial formation of turbulence, as well as to still it after it has been formed.

As Equation (10) applies to any channel by dividing it into elementary longitudinal sections, it will apply to a weir, either with reference to the entire cross-section, or to the elementary filaments separately. It is clear that the loss of head in friction depends on all the variables on which the coefficients depend, and also on Reynold's number. If $f = 0$ (no turbulence) the result is stream-line flow. In either kind of flow, the total coefficient decreases with an increasing Reynold's number, $\frac{m\,V}{\nu}$, if f' and f do not change sufficiently to the contrary as seems usually to be the case. (Note the behavior in the vicinity of the critical value of Reynold's number.)

Observe that Equation (10) measures merely the deterrent action of applied friction. That this friction is extremely small for weirs becomes apparent when the condition of a weir is compared with the condition of a canal, or river. Even with large values of the friction factors and with balancing slopes of only a few inches per mile, the velocities in rivers and canals are considerable. In the case of weirs the conditions are reversed, the surface slopes being far greater, while the friction is almost a vanishing quantity. This is due mainly to the small value of l, which attaches to weirs, in Equation (10), but the values of f' and f also become small, for weirs. However, it is well to consider the form of the coefficients in Equation (13).

Almost the entire obstacle to the surface slope and velocity over weirs lies in the acceleration of the spilling water above and beyond the crest. A frictionless weir would deliver only a little more water. Consequently, hydraulic friction is of little or no account in its effects on weir discharge, unless the head is abnormally small or the kinematical viscosity abnormally large. That the acceleration at Keokuk is very important, especially in furnishing a gauging section free from turbulence, was mentioned by the authors.* In such a section the effect of any turbulence near the piers must be extremely small, relatively.

In preparing their paper, and in executing their tests, the authors have been careful not to say or do anything which will admit of any great criticism, so that, actually, there is not much to criticize. However, it may be pertinent to comment favorably on some of their statements. Perhaps the main value of the experiments, other than the great practical utility of a ready means for determining exact coefficients for weirs of the Keokuk type, and approximate coefficients for other types, is the information concerning the interior of the nappe.† It would have been of great value also to determine internal pressures, but, if this was not done, the writer knows well that one is not usually war-

* *Proceedings*, Am. Soc. C. E., February, 1929, Papers and Discussions, p. 317.
† *Loc. cit.*, p. 325.

ranted in going far beyond the immediate objects of experiment to accumulate data on concomitant phenomena.

For many practical purposes Fig. 14* will be all that is desired, but there is need for a true weir formula, especially as an aid in original design. Much of what the authors have done will be useful in framing such a fundamental theory. It is true that there are some remarkable studies in hydrodynamics, but, when it comes to weirs, the theory is lacking, even for the case of two-dimensional flow. The remarks of the authors are, therefore, of very great interest.

They state† four significant facts, as follows: (1) Velocities are remarkably uniform within the nappe at a given depth below the pond level; (2) velocities within the nappe increase downward and friction is very small; (3) at the entrance to the nappe, velocities are higher at the bend around the pier noses; and (4) velocities at the entrance to the nappe are retarded by the restricted, and relatively constricted, paths along the angular corners.

The opinion may be expressed that one reason for the increase in velocity within the nappe, passing downward, lies in the fact that the spillway crest is curved in a vertical plane, and the radius is directed downward toward the center of curvature. Thus, the water in its progress is given an opportunity to turn downward, so that the centripetal acceleration, $\frac{v^2}{r}$, produces an upward directed centrifugal reaction which tends to support the weight of the water above, thus causing a decrease of internal pressure and a resulting increase in velocity, passing downward when comparing conditions. The reverse will be the case in the depression over an apron at the foot of an ogee dam. Velocities will be higher at the surface than at a depth, while the pressure will increase downward, because the concavity of the water surface faces upward. This is exactly the effect obtaining in an eddy with vertical axis (for example, water rotating rapidly in a pail), the difference being that the axis of rotation over the weir is horizontal. This same logic explains the increase in the velocity around the bends at the noses of the piers. The effect is the result of decreased pressure toward the center of curvature approximately according to the formula,

$$\frac{dp}{dr} = \frac{w}{g}\frac{V^2}{r} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (14)$$

Equation (14) would be exact if the viscosity were zero; that is, when there are no tangential tractions acting on elementary surfaces along which there is a tendency to slide. In hydrodynamics, when there are no such tractions, it has been assumed that v varies inversely as r, which leads to the "irrotational" form of vortex. There is another more or less present cause for reduced pressure on the crest and down along the spillway; that is, the siphonic action of the column of water resting on and against the spillway.

With reference to Fig. 14, it was suggested that possibly the velocity at the surface of the nappe may exceed that due to the head below pond level on the surface point in question. The possible shearing traction exerted by the more rapidly moving water below seems plausible, as a cause, at first sight,

* *Proceedings*, Am. Soc. C. E., February, 1929, Papers and Discussions, p. 328.
† *Loc. cit.*, p. 325.

but the fact that the excess velocity is negligible, compared to what one might expect, raises some doubt. One may imagine a weir discharging a very viscous liquid, say semi-liquid tar. With that in mind there does not appear to be any real connection between actual velocities and the broken-line curve of "Velocity Corresponding to Head below Pond Level".

Relative to the Keokuk weir, it may be pertinent to remark that the writer made some study of the plans for that weir and the possible coefficient of discharge, long before it was built. A number of engineers then entertained the idea that the adopted weir coefficients were too small for that type.

The writer's experience on the St. Lawrence and many other large rivers leads him to believe that, if the modeled reach is not too long (say, a mile or two), models using water give surprisingly accurate reproductions of flow. Perhaps longer reaches might prove satisfactory. He does not doubt the approximate accuracy of a model of the Keokuk spillway to a scale ratio of 1 to 100. However, the writer has shown* that a mercury "model" of water about one-fifth the full size will give theoretically exact results. That being true, it should be possible to secure the same degree of accuracy with a mercury model one–five hundredth of the full size as with a water "model", one-one hundredth of the full size. One should not hesitate to test and rely on a mercury model of the Keokuk Spillway, one-two hundred and fiftieth of the full size, although it would have to be "built like a watch". Such a model spillway must be built of suitable materials in proper condition as to smoothness, etc., in order to avoid distortion caused by excess viscosity and the presence of surface tension.

In closing, the writer may state that he can confirm the necessity of "staying" the meters in swift water. He has used meters in the rapids of the St. Lawrence where there were velocities approximating, if not as great as, those experienced at Keokuk by the authors.

As to the weir, the writer has made some calculations for the internal pressures at several points within the nappe (approximately, at least) and believes that it would be quite possible to frame a true weir formula, basing practical coefficients (dimensionless) on the results presented in the paper.

* "Ice Diversion, Hydraulic Models, and Hydraulic Similarity", *Transactions*, Am. Soc. C. E., Vol. LXXXII (1918), p. 1187, footnote.

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PAPERS AND DISCUSSIONS

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EXPERIMENTS TO DETERMINE RATE OF EVAPORATION FROM SATURATED SOILS AND RIVER-BED SANDS

Discussion*

By N. W. Cummings, Esq.

N. W. Cummings,† Esq. (by letter).‡—The author states§ that covers were provided to protect the tanks from rain. Presumably, they also prevented solar and sky radiation from reaching the moist surfaces under study because the author states further that a marked reduction in evaporation loss occurs when the covers are in place.

The use of the covers causes the experiments to represent a very important set of conditions, because a vast proportion of moist soil and other earthy material in which engineers are interested is shaded. This fact does not, however, destroy the interest which attaches to a comparison of the shaded and unshaded condition.

When the surface is shaded, nearly all the energy required for supplying the heat of vaporization necessary for converting the water from the liquid to the vapor state, is derived from the air that passes over the evaporating surface. On the other hand, when the surface is unshaded, this atmospheric component of the energy is usually small; it averages about 20% and is in the direction from water to air. This means that air temperature and humidity at the ground level are proportionately vastly more important when the surface is shaded than when it is unshaded.

This is evident from the fact that, in the case of the unshaded surface, atmospheric conditions at the ground level can affect only the smaller components of the energy; they can have no appreciable effect on radiation which is by far the largest component.

* Discussion of the paper by Ralph L. Parshall, Assoc. M. Am. Soc. C. E., continued from September, 1929, *Proceedings*.

† Research Associate, The Scripps Institution of Oceanography, Univ. of California, La Jolla, Calif.

‡ Received by the Secretary, July 29, 1929.

§ *Proceedings*, Am. Soc. C. E., April, 1929, Papers and Discussions, p. 849.

It is undoubtedly due, in large measure, to this fact that the depth of evaporation from a standard pan agrees as closely as it does with the loss from a lake subjected to the same sky conditions. The average humidity and air temperature over the lake surface are frequently not the same as over the surface of the water in the pan, yet the depths of evaporation seldom differ by more than 30 per cent.

When the surface is shaded, however, making the atmospheric component of the energy the important factor, there is no reason to expect that results from a small tank will bear anything approaching a definite relation to the loss from a large surface. The atmospheric component of energy depends on both temperature and humidity and as the air passes over an extended surface which is cooler than the air, as a shaded surface is almost sure to be, both temperature and humidity must change in such a direction as to decrease evaporation. Consequently, the loss per unit area might reasonably be expected to decrease very materially, as the area itself increases.

Engineers are confronted, therefore, with the necessity of finding the relation between the loss from a small surface and that from a very large surface under various conditions of wind, air temperature, and humidity when both surfaces are shaded. It is probable that some studies by Jeffreys* may be valuable in connection with this problem.

The fact that air temperature at the ground level does not have any marked influence on the largest energy component reaching an unshaded surface may seem inconsistent with the well established relation between air temperature and evaporation from lakes. The apparent contradiction may be easily explained, however, by noting that radiation cannot be controlled by atmospheric conditions at the ground level, even if the temperature may roughly indicate its magnitude.

* Summarized by Humphreys in "Physics of the Air."

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PRE-DETERMINING THE EXTENT OF A SEWAGE FIELD IN SEA WATER

Discussion*

By Warren E. Howland, Esq.

Warren E. Howland,† Esq. (by letter).‡—The writer would like to inquire whether the experiments from which Equation (17)§ was derived, were conducted as illustrated by Fig. 1.‖ That is, was the spread of the field on the surface determined "by observing the time when the edge of the field passed fixed points along the edge of the raft and along a plank cantilevered over the water at right angles to that edge"?¶

If t in Equation (17) refers to the time required for the colored water to reach a distance, x, from the point of discharge, it seems to the writer that the formula and the equation derived from it:

$$V = \frac{\alpha}{x^{0.50}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (37)$$

refer merely to conditions that occur when the fresh water is first discharged into the salt water rather than to conditions after the flow may have become steady. Is not the condition of steady flow of greater interest than the transitory condition of initial flow? Might not the two conditions be entirely dissimilar?

The authors describe a series of observations made at Long Beach, Calif. They state that a rough check on the thickness of the field was made by "observing the time required for chips of wood to float past fixed points in one

* Discussion of the paper by A. M. Rawn and H. K. Palmer, Members, Am. Soc. C. E., continued from September, 1929, *Proceedings*.

† Asst. Engr., State Dept. of Health, Hartford, Conn.

‡ Received by the Secretary, August 12, 1929.

§ *Proceedings*, Am. Soc. C. E., May, 1929, Papers and Discussions, p. 1178.

‖ *Loc. cit.*, p. 1170.

¶ *Loc. cit.*, p. 1171.

direction from the outlet".* Presumably, the condition studied was more nearly that of steady flow. From these observations they conclude that:

$$V = \frac{\alpha}{x^{0.58}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (38)$$

In this case, the exponent of x is 0.58 instead of 0.50 as in Equation (37). Is this to be considered as a reasonable check, or does the difference between the two values represent an actual difference between steady flow and initial conditions, or are the experiments that lead to the two equations entirely incomparable?

The authors have not made themselves entirely clear as to the method used in computing the extent of the sewage field in the case of current flow. In the example given to illustrate Case 1,† they find that in quiet water the sewage would travel 12 000 ft. before attaining a dilution of 225; but the time required to travel this distance would be 24.5 hours. In the case of current flow, the original point in the water, hypothetically, is then 44 500 ft. away from the new point where sewage is entering. Is it to be supposed that the dilutions and the relative velocities at corresponding distances from the point in the water where the sewage originally entered are the same as they would be if the sewage were still coming in at this original point?

Apparently, the authors made this assumption when they added 12 000 and 44 500 to obtain $e = 56\,000$ ft., which is given as the total distance traveled by the sewage, presumably to attain a dilution of 225. This value of e is further corrected to 13 150 to conform to the hypothetical conditions as stated,‡ but the alteration suggested does not seem to correct the error of the original assumption.

To state the question differently: Is not the case of sewage inflow into a moving current somewhat similar to the discharge of fresh water from a slowly moving boat? In the latter case a narrow band of brackish water is left behind and it immediately spreads sidewise, mixing with the salt water. The water at each point in the center of the spreading band is continually attaining a greater dilution by mixing as well as by actual removal of the fresh water once present. The writer believes that the contours of equal dilution, under such conditions, would be narrow ellipses or, perhaps, egg-shaped figures, but the dimensions might be difficult to compute.

The paper is of interest to sanitary engineers in Connecticut in their work of guarding health at bathing beaches.

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* *Proceedings*, Am. Soc. C. E., May, 1929, Papers and Discussions, p. 1186.

† *Loc. cit.*, p. 1189.

‡ *Loc. cit.*, p. 1190.

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WATER SUPPLY FROM RAINFALL ON VALLEY FLOORS

Discussion*

By Messrs. Harry F. Blaney and C. W. Sopp.

Harry F. Blaney,† Assoc. M. Am. Soc. C. E. (by letter).‡—The increasing demand for water for irrigation and domestic purposes in the semi-arid areas of the Southwest has created a need for more definite information as to what proportion of rain falling on the valley floors penetrates to the ground-water supply. Mr. Sonderegger's paper is a valuable contribution to the study of this complex subject.

Reference is made§ to some estimates, by the writer, of winter evapotranspiration losses and soil moisture deficiency at the beginning of the rainy season. Part of these are conclusions drawn by the author based on the writer's estimates. It should be definitely understood that these are preliminary and may be modified by subsequent information. It was necessary at that instance, to make an estimate of the contribution of the rain falling on the valley floor to the ground-water supply, for the purpose of completing the hydraulic accounting in the Santa Ana River report.‖

The following is a brief description of the method used. Rainfall penetration on the valley floor below the root zone was estimated indirectly by assigning values to evaporation, transpiration, soil moisture deficiency, and surface run-off as deduced from one season's work in the Santa Ana area, and by corroborating data secured in San Diego County and San Fernando Valley. These were analyzed and deducted from each rain storm, and the remainder of the rain was considered to penetrate below the root zone and eventually reach the ground-water. Assumptions are for average soil conditions, and no attempt was made to show the effect of soil texture on the depth of penetration. Values for the factors were assigned as follows.

* Discussion of the paper by A. L. Sonderegger, M. Am. Soc. C. E., continued from September, 1929, *Proceedings*.

† Irrig. Engr., Div. of Agricultural Eng., U. S. Dept. of Agriculture, Los Angeles, Calif.

‡ Received by the Secretary, August 5, 1929.

§ *Proceedings*, Am. Soc. C. E., May, 1929, Papers and Discussions, p. 1144.

‖ "Santa Ana River Investigations", *Bulletin 19*, State of California, 1929.

Evaporation.—Temperature, wind velocity, humidity, type of soil, kind of vegetation, transpiration, altitude, interception of rain by vegetation, period between storms, etc., are some of the many factors that affect the evaporation loss after a rain storm.

From observations it was found that the evaporation loss from a bare soil in the winter months very nearly equals the loss from a free water surface until the time the soil drains to field capacity. After that, the surface evaporation loss was readily determined by soil sampling. The best data available indicated that the average evaporation loss from the top-soil is about ½ acre-in. per acre after each rain storm.

Transpiration.—After careful consideration of unpublished data from co-operative irrigation investigations* in Northern San Diego County, covering two seasons, the total average transpiration for all active growing vegetation was taken as 6 acre-in. per acre during the six winter months, or 1 acre-in. per month. The rate of transpiration depends upon the crop. Other factors, such as temperature, air movement, humidity, available soil moisture, etc., also influence the rate of transpiration.

Investigations have shown that bare lands, vineyards, and deciduous orchards that are clean cultivated, have no material transpiration loss during the winter period.

Soil Moisture Deficiency.—In calculations of rainfall penetration, the deficiency of soil moisture below field capacity at the end of the summer season must be reckoned in analyzing the following rainy period. There will be no appreciable downward penetration until all the soil within the root zone has been filled to field capacity. The initial moisture content of the soil at the beginning of the rainy season will vary with the kind of crop, depth of root zone, type of soil, amount of irrigation, depth of water-table, etc.

After considering many observations made in Southern California, the values given in Table 14 were taken for the deficiency of soil moisture at the beginning of the rainy season, for average soil under various conditions.

TABLE 14.—DEFICIENCY OF SOIL MOISTURE.

Description of land.	Deficiency, in acre-inches per acre.
Bare land	1
Irrigated crops (except deciduous)	3
Grain, weeds, and grass (non-irrigated)	5
Deciduous trees and grapes	7
Native brush	7

Run-Off.—Hydrographers of the Santa Ana investigation determined the run-off rate per square mile on certain known areas. These rates were used also on undetermined areas.

Calculations of Rainfall Penetration.—In general, it was found that every season must be studied separately in order to arrive at the penetration for

* "Irrigation Water Requirement Studies in San Diego County, Calif.", by S. H. Beckett, Harry F. Blaney, and C. A. Taylor, Univ. of California and U. S. Dept. of Agriculture.

that season. The same seasonal rainfall may give entirely different penetration, due to varying intensity and distribution of storms. For computing the amount of rainfall penetrating below the root zone during the season, 1926-27, the values in Table 14 were used. Known rainfall records as near as possible, in total seasonal amount to the required average for an area, were used. An example of detail calculations for rainfall observed at the U. S. Weather Bureau Station at San Bernardino, Calif., is given in Table 15. The rainfall for the season, 1926-27, was 20.55 in. Table 16 contains a summary of estimates obtained for varying rainfall, by interpolating between calculated quantities.

TABLE 15.—EXAMPLE OF DETAIL CALCULATION OF RAINFALL PENETRATION FOR IRRIGATED CITRUS LAND, IN ACRE-INCHES PER ACRE.

Storm period.	Deficiency of soil moisture.	Rainfall.	Consumptive Use.*		Run-off.	Penetration below root zone.
			Transpiration.	Evaporation.		
1926-27:						
November 12-13.....	3.0	0.15	0.5	0.2	....	....
November 24-27.....	3.5	2.03	0.4	0.5	....	....
December 3- 9.....	2.4	1.68	0.1	0.5	....	....
December 12-13.....	1.3	0.10	0.3	0.1	....	....
December 18-23.....	1.6	1.30	0.7	0.5	....	....
January 10-12.....	1.5	0.41	0.4	0.4	....	....
January 20-23.....	1.9	0.95	0.4	0.5	....	....
February 4- 5.....	1.8	0.93	0.4	0.5	....	....
February 11-18.....	1.8	8.77	0.2	0.5	0.8	5.5
February 22-24.....	0.0	0.13	0.3	0.1	....	....
March 3- 5.....	0.3	1.15	0.2	0.5	....	0.2
March 9-10.....	0.0	0.28	0.7	0.3	....	....
March 28-30.....	0.7	1.23	0.4	0.5	....	....
April 10-12.....	0.4	0.94	0.6	0.5	....	....
May 1.....	0.6	....	....	....	....	....
Total penetration.....	.....	.....	.....	.....	.....	5.7

* Transpiration and evaporation after the initial data are computed for period from second date on line to second date on line below.

The State Division of Water Rights of California recognizes the importance of considering rainfall penetration in water supply studies and gives some interesting data in its recent report of the San Gabriel investigation.*

TABLE 16.—ESTIMATED RAINFALL PENETRATION BELOW ROOT ZONE, IN ACRE-INCHES PER ACRE, FOR SEASON 1926-1927, SANTA ANA RIVER AREA.

Seasonal rainfall, in inches.	Irrigated lands (excluding deciduous and vineyards).	Deciduous and vineyards.	Grain and grass land.	Brush land.	Bare land.
9	0.0	0.0	0.0	0.0	2.5
12	0.0	0.0	0.0	0.0	5.5
15	1.3	2.2	0.0	0.0	8.4
18	3.9	5.0	2.1	0.0	11.3
21	6.4	7.7	4.5	2.2	14.2
24	8.9	10.5	6.9	4.7	....
27	11.5	13.3	9.4	7.2	....
30	14.0	16.0	11.8	9.7	....

* "San Gabriel Investigation", by Harold Conkling, *Bulletin* 7, State of California, 1929.

At the request of the State Engineer of California a co-operative investigation is now being conducted by the Division of Agricultural Engineering, U. S. Department of Agriculture, to determine the penetration and storage of rain falling upon the valley floors of the Santa Ana River area in Southern California. This study will cover a four-year period.

In connection with this investigation a large number of rainfall penetration stations have been established on predominating soil types throughout the area. Measurements are being made of rainfall, evaporation, transpiration, surface run-off, and deep percolation. Soil samples are taken with standard soil tubes to depths of 12 to 18 ft., which is well below the root zone of most crop and native plants. In this way the storage of rain water in the soil and the downward percolation are determined. Ten of these stations are especially equipped for intensive work.

Shafts and tunnels have been dug at several locations along the foothill area where the ground is too rocky for soil sampling. The downward percolation of rain water is being measured at the tunnels. At one shaft near San Bernardino artificial rain has been applied during the past two seasons and the downward movement of water was observed at tunnels 12 and 20 ft. below the ground surface.

Since a large portion of the rainfall absorbed by the soil is lost by evaporation and transpiration, field plots are being intensively sampled throughout the year to determine the consumptive use of water by various crop plants and native vegetation.

Unfortunately, the rainfall in the Santa Ana River area has been below normal during 1927-28 and 1928-29 so that no final conclusions have been reached as to the amount of rainfall penetration.

Mr. Sonderegger is to be complimented on his excellent analysis of a method to determine rainfall penetration on the valley floors by comparison with mountain run-off.* However, the writer is of the opinion that usually the yield of water in mountain areas is essentially different from that resulting from rainfall penetration on valley floors.

There is an initial deficiency of soil moisture within the root zone, at the beginning of each rainy season. This is a variable factor dependent on plant life, depths of root activity, soil type, and depth of soil. The soil on the valley floors is generally of such a depth that the root activity is a maximum under native conditions, while in the mountain areas, bed-rock usually is near the surface, and in all probability there is root activity throughout the entire soil cover, the depth being limited only by bed-rock.

Rainfall penetrating below the root zone on the valley floors is at once out of reach of the overlying cover, except in areas of high water-table. In the mountains where the soil is shallow the condition is different. There the water is continually within reach of plant roots until it escapes into the stream channels or deep alluvium. It is only when the rate of drainage toward and along the stream channels is greater than the rate of evaporation and plant transpiration that there is any material yield of water from a mountain area.

* *Proceedings*, Am. Soc. C. E., May, 1929, Papers and Discussions, p. 1152.

Another modifying factor is the steepness of the slopes of a mountain water-shed. There is a far greater actual area of plant cover than the projected area used in determining the quantity of water resulting from a given depth of rainfall in inches. Conditions then are different in mountain areas than on valley floors, even for native brush cover; but further than this, the major portion of the valley floors is cultivated and much of it is irrigated. The depth and character of root activity of cultivated crops are widely different from that of native brush cover.

C. W. SOPP,* ASSOC. M. AM. SOC. C. E. (by letter).†—The author is to be commended for his outline of methods for computing a source of water supply of great importance to communities dependent on ground-water developments.

The writer believes that, where the water-table is close to the surface, the method based on the rise of water levels‡ is the most satisfactory if used with porosity data obtained from many well logs. This method may be applied also where the water-plane is at considerable depth, because the moisture in the alluvium between the root zone and the water-table is always practically up to field capacity.

This statement is based upon an analysis of nineteen samples of sands taken from a shaft dug in recent alluvium near Pasadena, Calif. These samples were taken from depths of from 75 to 170 ft. at the end of a season in which the total precipitation was only 13.73 in. This condition permits rapid movement of moisture, penetrating below the root zone, to the water-table, and the resulting rise of water levels, even at depths of 150 ft., is noticeable within a short time. A study of the initial rise of water levels in eight wells, observing two heavy storms for each well, showed an average rate of movement downward of 10 ft. per day. This is under previously saturated conditions of top soil.

The method of comparison with run-off from adjacent mountains is the easiest to apply, but is liable to wide differences, depending on the judgment of the engineer. The extension of the measured mountain run-off data to valleys which inherently differ in slope, soil, cover, and culture, is difficult. For example, Fig. 6,§ using average rainfall, shows a variation in run-off of 30% for similar mountain drainage areas.

The rainfall run-off relation illustrated by Fig. 8,‖ agrees with a law the writer has formulated for Southern California streams; the percentage run-off is equal to the seasonal rainfall, in inches, less ten, up to an annual precipitation of 60 in. As an illustration, with a seasonal rainfall of 60 in., the run-off, and consequently the evapo-transpiration losses, is 50%, or 30 in. The maximum consumptive use of forest cover on Southern California water-sheds is about 30 in.

There is an additional method which the author has not mentioned, and that is, to analyze the rainfall by storms and to consider that all precipitation—

* Asst. Engr., Water Dept., Pasadena, Calif.
† Received by the Secretary, August 12, 1929.
‡ *Proceedings*, Am. Soc. C. E., May, 1929, Papers and Discussions, p. 1162.
§ *Loc. cit.*, p. 1153.
‖ *Loc. cit.*, p. 1156.

after deducting run-off, evapo-transpiration losses, and moisture required to bring the soil in the root zone up to field capacity—moves downward and ultimately reaches the ground-water. This method gives conservative quantitative results. The principal criticism is that, due to collection of rainfall in depressions, some ground-water replenishment will occur even with small precipitation.

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THE PLANNING OF CAPITAL CITIES: DENVER, COLORADO

Discussion*

By Morris Knowles, M. Am. Soc. C. E.

Morris Knowles,† M. Am. Soc. C. E.—The City of Denver is one of the newer capitals of the West—one that has many rare combinations of outdoor expanse, scenery, and other attractions, the value of which is so well recognized that plans are being made not only for the city interior but for all the surroundings.

The author properly calls attention to the fact that most cities of reasonable size, even if characterized by one particular line of activity, are, to a certain extent, cosmopolitan in nature. Few cities, like few persons, can well succeed in, nor are they destined for, a single-track existence. There are not many capital cities that claim to be devoted wholly to Governmental functions. Even in the National Capital, a well organized committee is having a survey made to discover whether or not more business can be attracted to the Federal City; and, also whether perhaps industry of a light, unobjectionable nature cannot well be conducted—not too near Governmental buildings.

Is it not true, then, that all cities, even capitals must have a three-fold purpose: (1) To provide homes—places in which to live; (2) to provide means of livelihood—facilities for working, doing, creating; and (3) finally to provide for education, enjoyment, and recreation?

It may be worth while to pause for just a moment on the second stated object of cities, because there has been some change of feeling in the United States in regard to the strenuous competition between cities; there is some doubt as to the wisdom of the chambers of commerce, and of the people, in striving to enlarge and increase their cities, as if size alone were the desired object.

Much is heard as to how the city shall be made greater industrially or more important as a business market. There is discussion of a new activity

* This discussion (of the paper by S. R. De Boer, Esq., presented at the Technical Session, Denver, Colo., July 13, 1927, and published in September, 1929, *Proceedings*) is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† Pres. and Chf. Engr., Morris Knowles, Inc., Pittsburgh, Pa.

called the "industrial survey"; an important and desirable review. Frequently, however, such survey has been confined to factories, types of industries (good and bad), market conditions, transportation conditions, etc. In consequence, it sometimes has become so concentrated upon these subjects of industrial supremacy, important as they are, that there has been a complete neglect of reckoning of the amenities, vital statistics, social values, community health, educational opportunities, governmental operations and effect of taxation system, the closeness of adherence to a good city plan and zoning; recreational opportunities, etc.

Thus, there has dawned on some a feeling that such communities are becoming unbalanced. That they are forgetting the complete development of which the author has written, and are devoting themselves to one thing. The Chamber of Commerce of the United States has called attention to the fact that there is danger in this kind of ambition and in this kind of survey when it attempts only to picture one's community as an aggressive, wise, thorough organization, seeking for industry and nothing further.

Study has been given, by the Civic Development Department of the Chamber, to the subject of what has been called a "Master Survey". Such a study would review the community in a large and comprehensive way and would consider all municipal functions. After thus learning about itself and what it must do to make itself attractive to industry—and to the people and their families who will engage in such pursuits—the city will be ready for the more detailed analysis of what it should do to care for the manufacturing and the business which it hopes to secure.

The author has called attention to the subject of utilities.* One often forgets that public utility planning is city planning. The city engineer may be said to have been the original city planner of America, because if he were "on the job", he never did anything without considering, as far as was humanly possible, what the future was going to be for that particular function, and how it was going to affect the growth and development of the city. As the author has wisely stated, one of the most important things for a city, particularly for a capital city, if it desires to proclaim itself as an attraction for tourists, is the water supply. This, in fact, is true of all forms of public utility service, but the Eastern cities never have been so seriously concerned with the question of water supply as those in the West because seemingly, but not absolutely, they are affected by less arid conditions. Nevertheless, their very prodigality has brought them trouble. In New York, N. Y., and Boston, Mass., for instance, it is becoming necessary to go farther and farther away for new supplies, because near-by sources have either become contaminated or polluted, or industrial wastes have made their use undesirable.

There is a Biblical truth which may be applied in such cases: "What is a man profited, if he shall gain the whole world, and lose his own soul?" To paraphrase, it might be said concerning some Eastern States, "What does it profit a city to plan for wonderful industrial growth and allow the streams to become so polluted that the people working in the industries have no suitable

* *Proceedings*, Am. Soc. C. E., August, 1929, Papers and Discussions, p. 1556.

drinking water?" And, conversely, "Where is the benefit if some large city of the arid West must provide its own needs by taking life itself from the very crops which are themselves needed for sustenance for the people of the city?" These things are by no means minor or insignificant phases of city planning. Cities must give way to the least important in all these problems if they are to have the well-rounded development necessary for people to live and exist as they should.

Mention has been made of the planning of Washington, D. C., and the creation, after some years of discussion and controversy, of the Capital Park and Planning Commission. This promises a new study and a new development commensurate with the dignity of the National Capital. In passing, it may be well to call attention to the rather important part which the Society has taken in the counsel and discussion, and in the decision, for wise legislation and the appointment of civilians to aid those in the official life of Washington, in providing that kind of planning which will insure a National Capital of which the whole country will be proud.

Recently, some interesting historical data have been brought to life in Western Pennsylvania, concerning the planning of what was intended to be a model community on the bank of the Ohio River, about eighteen miles below Pittsburgh. The plan itself antedates by several years the L'Enfant plan of Washington. For information concerning this notable early bit of planning, credit is due to the Historical Association that has carefully preserved the records of what was known as the Harmony Society of Economites, a German religious sect whose followers came to this country in the early part of the Nineteenth Century. First, they settled at Harmony, Pa., on the Conoquenessing Creek. Later, they moved to New Harmony, Ind., an American hobby of Owen, the English mill owner. Finally, they abandoned this city because of an epidemic of malaria and, in 1824, moved to Economy, now Ambridge, Pa.

They were a frugal, careful, substantial people; they gained much of the world's goods and generally were considered to have a far-seeing wisdom. What is not generally known, however, is that they settled upon a site already laid out, which they bought from the heirs of one, Col. Isaac Melcher.

In 1786, Colonel Melcher and his associates secured from the Colonial Office a grant of 1 000 acres and laid out what he and his friends thought would be the capital city of Westmoreland County, which at that time was practically all of Western Pennsylvania. Some streets were laid out to be 99 ft. wide and others, 66 ft. The locations of the important buildings and churches were indicated. The town lots were 44 ft. wide and 221 ft. deep. A square of ample size was provided for a large public building and this site, later, was utilized by the Economites, for what they called "the great meeting house". This structure still exists. The land now is under the control of a Board of Trustees appointed for the preservation of the early town and building. The old plan follows the rectangular plan originated by William Penn, and shows an early appreciation of the design of a capital city. This example truly represents that old-time phrase that "there is nothing new under the sun."

MEMOIRS OF DECEASED MEMBERS

FERDINAND FOCH, Hon. M. Am. Soc. C. E.*

DIED MARCH 20, 1929.

Ferdinand Foch was born on October 2, 1851, at Tarbes in the Department of Hautes Pyrénées, France. Although his ancestry was not illustrious, he was sprung from the class of country gentry, a class that always forms the backbone and main strength of every people, and particularly of the French. His father was a practising lawyer, a calling which, however, did not appeal to the son, whose inclination was toward mathematical pursuits, although his strong religious sentiments at one time led him to consider taking Holy Orders. His brother did so, becoming a priest of the Jesuit Order, but Ferdinand was entered in 1869 at St. Clément's College, Metz, to study for the Ecole Polytechnique.

The Franco-German War broke out the year following and young Foch promptly volunteered, but by the irony of fate the future Maréchal of France and conqueror of the Teutonic armies saw no active service, being drafted into a unit that was held in Central France away from the fighting line.

The war ended; M. Foch, discharged from the army, took his examinations for the Ecole Polytechnique, from which he was graduated, commissioned, and assigned to the Artillery in 1873. After a short service with troops he was attached to the General Staff, and, in 1895, was appointed a professor at the Ecole de Guerre, when his military rank was that of a Lieutenant-Colonel. In 1901, he was named Director of the Ecole, serving until 1905.

There is a pretty story that M. Clemenceau, then President of the Council, appointed Colonel Foch to the post without any previous knowledge on his part that he was being at all considered. Unfortunately, this story lacks confirmation. Colonel Foch was a candidate, believing that his career lay in teaching, and he was given the post after long and careful consideration. This was one of M. Clemenceau's greater acts. Colonel Foch not only had no political influence, but had incurred the hostility of the radical party then in power on account of his strong religious views and devout practice. M. Clemenceau made the selection of Colonel Foch solely on the score of merit.

While a professor he delivered a series of lectures on the Art of War, which have been published in two volumes under the titles of "De la Conduite de la Guerre" and "De les Principes de la Guerre", and have been translated into many languages. In the latter volume he analyzed the campaigns of Napoleon, who was his military idol and inspiration; and in the former, the major battles and strategy of the Franco-German War of 1870. These lectures are particularly interesting as he shows that, with only slight improvement in French strategy, the German plan of campaign would have broken down. For these conclusions he gave full authority by quoting official German orders.

* Memoir prepared by Wm. Barclay Parsons, Hon. M. Am. Soc. C. E.

In 1911 he was given command of the 13th Division of Infantry, the first body of troops that he had commanded since as a Captain he had been at the head of a battery of artillery.

When General Foch was 63 years old, or within a year of the time when an American army officer would be automatically retired "for age", the World War broke out. At that time he was commanding the Twentieth Army Corps with headquarters at Nancy, France. In July, 1914, he had been given leave and was visiting his country place, the Château de Transfeuntenisu, near Ploujean, on the Brittany Coast, to make ready against the enforced longer leave that he must soon take, when he received a peremptory order to return at once to his command. A few days later Europe was in ferment.

With the organization of the greatly enlarged French Army, following mobilization, there was a demand for officers to assume high and important rank. General Joffre had been made Commander-in-Chief of the French forces, and selected General Foch to command the Ninth Army. Thus, there was presented the extraordinary spectacle of an Army Commander, 63 years of age, whose military service had been almost exclusively confined to work on the General Staff, or in the lecture halls of the Ecole de Guerre. He had taken no part even in the small wars that France had carried on in the Colonies, nor had he ever handled large bodies of troops in the field. His experience had been wholly theoretical and didactic.

When General Joffre, while fighting masterly rearguard actions during August, 1914, in the retreat from Northern France, finally succeeded in placing his forces in such orderly arrangement along the Marne as would enable him to make a stand and by a counterstroke to attempt to seize the offensive, the Ninth Army occupied that portion of the line from Sezanne to Mailly le Camp with headquarters at Fère Champenoise. On the left was the Fifth Army commanded by General Franchet d'Esperey, and on the right the Fourth Army under General Langle de Cary. Opposed were parts of the Second and Third German Armies with Generals von Bülow and von Hausen.

On September 6, 1914, when the order was given to the whole line to stop retreating and to advance, no one saw more clearly than he, who had taught the theory of war, what the whole situation presented. If an advance could not be made, a further retreat with defeat was inevitable, while, on the other hand, an advance that did not completely dislocate the enemy's plan of attack would not suffice to avert impending disaster. For two days the German forces were thrown against the French and British line to break its resistance, and nowhere was the attack heavier than on the front of the Ninth Army. So violent was the pressure that General Foch had been forced to yield ground.

In his lectures he enunciated the principle that there was such a thing as the "Will to Victory", deducing from it that a battle is lost only when a commander believes himself beaten. On the afternoon of September 8, with his own resolve to win firmly fixed in spite of local reverses, he saw that the enemy forces had been drawn into an unfavorable position, which could be availed of by a rapid and daring shift of his own troops. It was then that he sent his famous dispatch, "My right heavily pressed, my center yields, situation excellent, I attack." It was the temporary faulty position of the forces in

front of him that presented the excellent situation. This message was intended to cheer the drooping spirits of men who had been in continuous retreat for four weeks and who had but recently come under his command.

General Foch attacked with such vigor that the enemy, whose extreme right wing was in difficulty, saw that an immediate retirement along the whole front was necessary to avert a disaster. Paris and France were saved.

When time has removed all personal bias and an impartial study can be undertaken to apportion credit and evaluate effect between the genius of Joffre and Gallieni, the surprise pressure that developed on the enemy's right, the fact that the enemy had outrun his reserves and supplies, and other causes contributing to the victory on the Marne, there would seem to be no question that General Foch's brilliancy in discerning an "excellent situation" in the midst of what appeared to be a crushing defeat, and his alertness in seizing it, will be ranked as one of the most potent factors.

With any further advance temporarily stopped the Germans endeavored to correct an initial error which they had committed when they left the channel ports free. To assist in their defense by co-ordinating the efforts of the British, French, and Belgian forces, General Foch was sent to Northern France with the title of Commander of the group of Armies of the North. His authority was limited, however, to the French forces, and his relations with respect to the British and Belgian Allies were those of a liaison officer. In this double capacity he remained until the end of 1916, taking prominent part in the Artois and Somme offensives, where there was some of the bloodiest fighting in the whole war.

Then, through one of these unfortunate developments in internal politics, which have no relation to the conduct of war, but which in a democratic government seem to be inseparable from it, General Foch was sent into temporary retirement, being ordered to Senlis "to rest", although later given nominal inspection duty and ordered to prepare a plan for resistance against a possible German invasion of Switzerland. In 1917, he was made Chief of the General Staff with headquarters in Paris, a position that carried no field command.

On March 21, 1918, the Germans began their last and great offensive. A wedge was driven between the British right and the French left just south of Peronne, involving the retirement of the British Fifth Army and the withdrawal of the French left. Not only was the whole area of the Somme, that had taken the Allies five months in 1916 to capture at appalling cost, regained in as many days, but additional territory was seized that had been held by the British or French since 1914. The enemy was in front of Arras and Amiens, and the main lines of communication from Paris northward were either cut or rendered useless as being under fire.

The situation was as desperate as it was on the Marne in 1914, and it was obvious that some drastic step must be taken to prevent a break-through to the Channel that would divide the Allies into two parts and involve disaster. As Field Marshal Haig put it, "We are fighting with our backs to the wall." There were three armies in the northern field co-operating but not correlated, French, British, and Belgian. There was a fourth, the American, just entering

the field. These armies were under their own individual commanders, who conferred and acted jointly as best they could, while preserving their own separate authority. They "loaned" each other troops and supplies, if sufficient emergency could be shown, but in accordance with the dictates of human nature, each commander reserved to himself the right to decide on the seriousness of the other's emergency and was reluctant to release reserves or material for fear that he might immediately find himself, in turn, in sore straits.

For three years it had been patent that this division of control was a serious handicap as opposed to the single will presented by the enemy, but as yet no nation was willing to accept an uncontrolled command vested in another national. Victory and defeat were now in the balance, and if the former were to be secured all personal antagonisms must be submerged into the greater consideration of the welfare of the common cause.

On March 26, 1918, a conference between the leading French and British military leaders and ministers representing the respective War Departments was held in the Hôtel de Ville, of Doullens, a small village about 20 miles north of Amiens and directly behind the front line, to determine a policy of joint action. It was at once agreed that complete unity in command could be postponed no longer, and the sole question was to find the man. Various names were proposed, even that of M. Clemenceau being brought forward, but after long discussion only General Foch had not been rejected. Sir Douglas Haig stated that he would accept Foch as Generalissimo and give him full support, an offer immediately repeated by General Pétain, then the French Commander-in-Chief. M. Clemenceau had General Foch waiting, because from the outset he was M. Clemenceau's candidate. He was called in and accepted the burden, so that finally after three and one-half years of blundering, a single directing force faced the common enemy. A few days later, General Pershing pledged the new Commander-in-Chief his support and that of the American Army, provided only that the latter should be used as a unit.

There is no parallel in history to the task that General Foch undertook that night in spite of his 67 years. The French, British, and Belgian Armies totaled nearly 10 000 000 men. They were wearied with almost four years of continuous fighting, during which time each had learned to think of itself as a separate unit working to some extent conjointly with others. Recently, they had received a blow that had sent them reeling and one that had nearly caused collapse. Guns in great number and material in huge quantities had been lost. Other blows were certain to follow. Could this great mass be welded into a single unit capable not only of withstanding the further attacks that were to come, but of assuming the offensive and striking back? That was General Foch's task, one that called for the stoutest "Will to Victory".

To-day is still too close to those great events when defeat was turned into victory, properly and fully to evaluate the service rendered by General Foch, and the manner in which he accomplished the task that had been assigned to him. To what extent he accepted and was guided by the advice of his Lieutenants, Haig, Pétain, and Pershing, is not as yet clear. Probably he left many details to each Commander, asking only that separate movements should conform to the general plan. His great accomplishment, as to which there will

probably be no question, was his success in amalgamating four armies into one, enabling him to treat reserves as one mass, which, whether in men or material, could be diverted or concentrated in such manner or place as he deemed most important. Yet that accomplishment meant victory, and alone justifies the enduring gratitude of the allied nations, of which America was one, and entitles General Foch to be accorded lasting fame. He has described himself as "No more than the conductor of the orchestra"; but what an orchestra!

The next attacks already planned by the enemy could not be averted, but by skillful handling of his forces, General Foch resisted them and gradually brought the offenesive to a halt, with Arras, Amiens, and other strategic points safely held. Relieved of the pressure of defending, he set about building up a united army that would be capable of taking a successful offensive. By midsummer his preparations were complete, and he planned to strike the enemy on July 18, in the direction of Soissons.

German headquarters had learned of the proposed attack through their spy system and hoped to escape it by attacking first. This they did early in the morning of July 15, and succeeded in crossing the Marne between Château-Thierry and Dolmans, to a depth of five or six miles. At first, it looked as if the enemy had succeeded in his move, but General Foch, after a careful examination of the situation, decided that the result placed the Germans in a more difficult situation than it did the Allies and decided to continue with his own plan unaltered, leaving but a sufficient force to restrain the enemy from making a further advance. He saw that they had exposed a weak flank, and that his previously prepared plan would compel them to withdraw across the Marne, or have their advanced troops cut off, and this without any sacrifice on his part. This decision well illustrates his method of carefully weighing all the factors at the time of a crisis and not allowing his judgment to be warped either by an excess of caution or a disinclination to change a predetermined plan, and, having reached a decision, to act with firmness. In this particular case it took courage to leave the enemy in his advanced position. It was this ability to think clearly and then to execute without flinching or compromising, that gained for General Foch the unwavering confidence of all ranks.

General Foch's attack was successful and was quickly followed by others in succession until the offensive was general from the Channel to Metz. Steadily under the direction of the master mind the wave rolled on until at the end of October the enemy, realizing defeat, opened negotiations for an armistice, which was signed on November 11, 1918.

In fixing the terms of this armistice, General Foch resisted what must have been a severe temptation for a personal satisfaction. Great pressure was brought to bear on him to continue the war until every German soldier had been driven from France, to sign the treaty on German soil and to lead a triumphal procession through Berlin. It would have been easy to find justification for such a course, especially as it was supported by popular clamor. The enemy was already in retreat, indicating that his power of resistance was broken, and his own recollection of the King of Prussia being crowned German Emperor at Versailles in 1870 and of the march of the victors down the Champs Elysées, must have been in his mind. He rejected all thought of

personal aggrandizement or unnecessary risk, however, arguing that there was no justification in prolonging the war one hour or shedding one drop of blood after the main objective had been gained, which, in this case, was the expulsion of the invader from France.

The war ended, General Foch made no effort to secure political advancement. He was a soldier fighting when his country needed his services and was not of the type of the "Man on Horseback" that France had always feared would come into being following a victorious war against Germany when the "stolen" Provinces would be returned. As soon as his military duties permitted, he withdrew to his estate of Transfeuntenisu.

All nations vied in heaping upon him every honor available. France made him a Maréchal and the Academy elected him as one of 40 "Immortals." Great Britain created him a Field Marshal and conferred on him the Grand Cross of the Order of the Bath and the Order of Merit. So it was with every nation associated with the Allied cause.

In 1921, he made his first and only visit to the United States. On December 6, he was received in the Engineering Societies' Building and was presented for Honorary Membership in all the Founder Societies, the only man who has ever received such distinction as a joint award.*

During 1928, his health began to fail and although he made the same determined fight against the one enemy who cannot be beaten, he was able only to postpone the inevitable. He died at his residence in Paris, on March 20, 1929. He was buried in the Invalides on March 26, 1929, close to his great hero, Napoleon.

Ferdinand Foch was married to Julia Bienvenue, by whom he had one son and two daughters. His son, an officer in the French Army, was killed at the outbreak of the war (August, 1914) in the Ardennes. It is related that when word of his son's death was brought to him he requested the members of his staff to withdraw and leave him alone for half an hour. When they returned they found him at his table studying his maps and prepared to carry on.

He was of medium height with a well-made frame. His face, although it showed energy and determination, had in repose a gentle, kind expression. His whole appearance suggested the man of action, but perhaps that of the man of affairs rather than the type of Roman conqueror that popular fancy has in mind for the military leader.

Marshal Foch was elected an Honorary Member of the American Society of Civil Engineers on December 6, 1921.

SAMUEL REA, Hon. M. Am. Soc. C. E.†

DIED MARCH 24, 1929.

Samuel Rea was born in Hollidaysburg, Pa., on September 21, 1855, the son of James D. and Ruth (Moore) Rea, and the grandson of General John Rea, of Chambersburg, Pa., who was an Officer in the Revolutionary War.

* For an account of the presentation see *Proceedings*, Am. Soc. C. E., January, 1922, Society Affairs, pp. 4-7.

† Memoir prepared by W. W. Atterbury, M. Am. Soc. C. E.

Before reaching the age of sixteen, Mr. Rea entered the service of the Pennsylvania Railroad Company as a Rodman in one of its Engineering Corps. With the exception of a few short intervals, he served in that organization during the remainder of his life as Engineer, Principal Assistant Engineer, Assistant Second Vice-President, Assistant to the President, First Assistant to the President, Fourth Vice-President, Third Vice-President, Second Vice-President, First Vice-President, Vice-President and, finally, President from January 1, 1913, to September 30, 1925. On the latter date he retired as President under the Pension Regulations. Mr. Rea was the only President to attain the age of 70 years in active service, none of his predecessors in that office having lived beyond 63 years.

His employment with the Pennsylvania Railroad Company and his active and vigorous interest in it through the period of its ever-increasing development and importance as the leading transportation system of the country, were the heart and soul of his existence—in fine, he lived the Pennsylvania Railroad.

His quick grasp of difficult questions, his exceptional memory, his natural ability to analyze and solve railroad problems, and the opportunity of growing up in close touch with the development of the large area served by the Pennsylvania System, all welded together in him an amazing knowledge of the property and the territory it serves. It may truthfully be said that he knew more about the physical and financial characteristics of the Pennsylvania Railroad Company, its history and problems, than any of his contemporaries.

The range of Mr. Rea's activities in the service of the railroad was extensive and diverse. Early in his career he centered his attention on the numerous branch lines of the Pennsylvania System which, in his case, meant not only their construction and operation, but also their corporate formation, financing, etc.

More than thirty years ago he foresaw the desirability and need of railroad consolidations as a factor that would contribute toward more efficient and economical operation of the railroads. The Pennsylvania System originally consisted of more than 600 constituent transportation companies, which at the close of Mr. Rea's administration in 1925, and largely through his intensive efforts, had been reduced through consolidations and acquisitions to 127 companies. His activities in this direction gave him the nickname among his associates of "Consolidation Sam."

He was connected with practically all these subsidiaries in the capacity of President or Vice-President, or as a Director. The acquisition of an interest in a large number of lines, such as the Long Island Railroad, the Norfolk and Western Railway, and others, was carried out under his direction.

His close association with former Presidents Roberts and Cassatt, and former Financial Vice-President John P. Green, served to broaden his outlook and increase his knowledge in many directions in the railroad field.

In the course of his work, Mr. Rea made the acquaintance of Gustav Lindenthal, M. Am. Soc. C. E., the noted bridge engineer, with whom his activities brought him in close association for many years. Mr. Rea took a

deep interest in the organization of the North River Bridge Company, of which he was one of the incorporators. The construction of this bridge would have provided an all-rail entrance into the heart of New York City. Failing to secure needed co-operation of other rail lines to assure the success of such a large project, the Pennsylvania Railroad Company proceeded independently to make its own plans for such an entrance by means of tunnels under the Hudson and East Rivers, and Mr. Rea was given direct charge of this work by former President Cassatt. This was most appropriate because, upon his appointment as Assistant to the President in 1892, he had been sent to London, England, to make an examination of the underground railroads then constructed and proposed in that city, and subsequently made a report thereon. Before this, in 1887, he had written a book entitled, "The Railways Terminating in London", a comprehensive study of the physical and financial condition of the English railroads. The success of this great tunnel extension, including the erection of the Pennsylvania Station in New York, N. Y., will always be classed as one of his greatest monuments.

He was also the Executive Engineering Head in the construction of the New York Connecting Railroad, including the Hell Gate Bridge, the longest arch span in the world, which connects the Pennsylvania and New Haven Systems and furnishes an all-rail connection for the Pennsylvania Railroad Company from the South and West with New England and Canadian points.

Mr. Rea took a keen interest in civic and welfare work, making liberal contributions of money and personal effort to worthy causes. He favored regional planning for the Metropolitan Area in and around Philadelphia, Pa., and was Chairman of the Regional Planning Federation of Philadelphia Tri-State District. He not only was Chairman of the Committee to raise funds to carry on this work, but also devoted a great deal of time and study to comprehensive planning for the future of this important section of the country. He was a member of the Board of Trustees of Bryn Mawr Hospital and headed the work of securing a large building fund for that institution. He was for many years President of the Board of Trustees of the Bryn Mawr Presbyterian Church and took a prominent part in building its new edifice, giving a great deal of time to the raising of the necessary money and actual construction work. He contributed the cost of the new organ with the understanding that it would contain no mark or plate showing the name of the donor. Fortunately he lived to see the Church building completed.

He was also a Trustee of the Pennsylvania Museum and, during his life, contributed a valuable collection of old English silver to the Art Museum in Fairmount Park, Philadelphia. This is one of the most important private benefactions the Museum has received.

Mr. Rea's interest in railroad transportation was not confined to the Pennsylvania System. His frequent trips throughout the country gave him the opportunity to observe methods of construction and operation on other roads, and the knowledge thus gained was of great value to the Government immediately after the United States entered the World War and before the

railroads were taken over at the end of 1917. For eight months prior to that time Mr. Rea and the executives of five other roads constituted what was known as the "Railroads' War Board," under the direction of which the competitive activities of all the important railroads of the United States were submerged, and their properties operated as a continental railway system so as to produce the maximum of National transportation efficiency.

At the time of his death Mr. Rea was a Director of the Pennsylvania Railroad Company and of several of its subsidiaries; also a Director of the Southern Pacific Company, the Philadelphia National Bank, the Bank of North America and Trust Company, the Equitable Life Assurance Society of the United States, the Philadelphia Saving Fund Society, the Bell Telephone Company of Pennsylvania, the Norfolk and Western Railway Company, and a member of the Philadelphia Gas Commission.

Although Mr. Rea did not go to college, having secured his knowledge of engineering through actual experience supplemented by keen observation and study at night, and by extensive travel at home and abroad, in later years he received several honorary degrees, including that of Doctor of Science, from the University of Pennsylvania in 1910; Doctor of Laws from Lafayette College in 1916; and Doctor of Science from Princeton University in 1916.

Mr. Rea was elected a Member of the Institution of Civil Engineers of Great Britain in 1891 and an Honorary Member in 1928, and, at his death, was the only American Member so honored.

On May 12, 1926, the Franklin Institute of Philadelphia awarded him the Franklin Medal, "in recognition of his outstanding work in the conception and construction of railroads, their terminals, tunnels, and bridges, and of his eminently successful application of the principles of science, economics and human relations to railway engineering and administration, in which he displayed vision, imagination and courage of high order".

He was married on September 11, 1879, to Mary M. Black, of Pittsburgh, Pa., and was looking forward to celebrating his Fiftieth Anniversary in 1929. They had two children, George Black Rea, who died in 1908 at the age of 27 years, and Ruth Rea, who is married to George B. Junkin.

Mr. Rea was a man of simple tastes, one who avoided ostentation and was beloved by all. He was devoted to his family and his life's work; he was a great reader and intensely interested in the growth of the country and its industries—a loyal friend and a great man.

The following is an abstract from the minutes adopted by the Board of Directors of the Pennsylvania Railroad Company at its meeting on March 27, 1929:

"Three years and a half ago, this Board recorded the termination of the active service of Samuel Rea, President of the Company, and paid tribute to his distinguished service. To-day we come, in the sorrow of bereavement, to record the termination of his life,—a life of accomplishment and distinction.

"Though, after his retirement from the Presidency, Mr. Rea continued, as a member of this Board, to devote much of his time, and to give the benefit of his extensive experience and fund of knowledge of its history and traditions, to the management of the Company's affairs, he found, in relief from the exactions of executive office, leisure to devote his talents to the solution

of problems of civic welfare, the betterment of his fellow men and the advancement of art.

"Mr. Rea's connection with the Company covered half a century. Innate talent, unusual intellectual endowments, industry, and an indomitable determination to know and to be ever of greater service, developed from the rodman of less than seventeen years the finished engineer and the master of railroad science. Each step in that development was characterized by devotion to the Company's interest and a single purpose to promote its welfare.

"This Company's foothold on Manhattan Island, and the welding of its lines to those in New England, have been called a monument to the vision and courage of Alexander J. Cassatt. The realization of that vision was committed to the hands of Samuel Rea, and its accomplishment stands as the most conspicuous monument to his professional skill and administrative ability. In the corporate and economic structure of the now vast system are other memorials, which, though unseen, are of no less importance to its welfare.

"In recognition of his intellectual attainments, institutions of learning have conferred honorary degrees, and scientific bodies decorations and honorary membership. Worthy tributes all to the man of genius and achievement, but dearer to those who mourn his loss is the willing bestowal of the greatest decoration which man can receive of man—that he was honored, respected and beloved as well for what he was, as for his culture and the fruits of his notable talents.

"The name of Samuel Rea is enrolled on history's pages with those of the distinguished men who have wrought the fabric of, and builded, each in his turn, on the great highway of the nation's progress.

"It is difficult in this record to pay just tribute to the genius and worth of so accomplished a man, and to adequately express the measure of our sorrow and loss in his death.

"His works are his enduring monument; the affectionate regard of those with whom he was associated, a tribute, more eloquent than words, to his worth".

Mr. Rea was elected a Member of the American Society of Civil Engineers on June 4, 1884, and an Honorary Member on June 6, 1921.

EUGENE HILARIAN ABADIE, M. Am. Soc. C. E.*

DIED APRIL 27, 1929.

Eugene Hilarian Abadie was born in St. Louis, Mo., on March 1, 1872, the son of Eugene S. and Mary (Snow) Abadie. He was educated in the public and private schools of St. Louis, and at Washington University.

From 1891 to 1892, Mr. Abadie was employed in the Shop and Engineering Department of the Wagner Electric Manufacturing Company assembling and testing electrical apparatus, and from 1893 to 1900 he was Secretary and Manager of Sales, as well as a member of the Executive Board of this Company. From 1901 to 1903, he was Manager of the Sales Organization of the Bullock Electrical Manufacturing Company, of Cincinnati, Ohio, and of the Wagner Electric Manufacturing Company, of St. Louis, directing and supervising the acquisition of engineering contracts.

* Memoir prepared by D. H. Sawyer, M. Am. Soc. C. E.

From 1903 to 1908, he was a member of the firm of E. H. Abadie and Company, Engineers and Contractors, during which time he designed and constructed the heating plant and power house for the State Buildings at Jefferson City, Mo. In 1904, he designed and built the central heating plant for the Pana, Ill., Gas and Electric Company, and, in 1905, he served as Engineer for the Southern Kansas Railway, Light, and Power Company, developed the project, and furnished a report for underwriters.

In 1906, Mr. Abadie designed and built all the underground conduits in Louisville, Ky., for the various public utilities. At that time he was associated with the late Arsene Perrilliat, M. Am. Soc. C. E., in the location of the New Orleans and Baton Rouge Electric Railroad, supervised the engineering, and wrote the engineering report. In 1907, he rehabilitated the Moberly, Mo., Gas and Electric Company and increased the connected load 300 per cent. He also designed and built the municipal power plant at Little Rock, Ark. In 1908, he designed a plant for stripping earth with steam shovels from a coal bed of the Lilly Jellico Coal Company, at Lilly, Ky., and, in a similar manner, mined the coal.

As a Constructing Engineer, Mr. Abadie designed the electric power generating plant for the Consumers Light and Power Company, at Fort Worth, Tex. As a Contractor, he built for the United States War Department, the sewer and water-works at Jefferson Barracks, Missouri. He also designed and installed a number of isolated and industrial steam and electric power plants in St. Louis and in the Central and Southern States. As a general or subcontractor, he contracted to supply mechanical equipment, comprising heating, ventilating, and lighting systems and steam and electrical power plants in shops, department stores, and other large buildings. From 1908 to 1917, he was a practicing Consulting Engineer, and was associated with Dr. George S. Hessenbruch, of St. Louis, during the last five years of this period. In addition, he was Secretary and Treasurer of the Industrial Engineers Corporation of St. Louis. In 1910, he was Consulting Engineer and acted in an advisory capacity to the Public Service Commission in matters connected with the valuation of public utilities of St. Louis.

In 1917, Mr. Abadie joined the United States Army, first as a Major of Engineers in the United States Reserve Corps. In July, 1917, he was assigned to the Construction Division of the Army as Supervising Constructing Quartermaster, having personal charge of National Army Cantonments and National Guard Camps (Camps Funston, Dodge, and Lee). In September, 1917, Major Abadie took charge of the construction of Camp Lee as Constructing Quartermaster, later going to Washington, D. C., as Supervising Constructing Quartermaster in charge of Camps Holabird, Jessup, and Normoyle, and the Army Tubercular Hospitals, at Denver and Azalea, Colo., as well as several smaller projects. In 1918, he took charge of construction matters connected with shops, camps, etc., of the Motor Transport Corps. In August, 1918, he was commissioned Lieutenant Colonel and served in that capacity until after the World War. In 1919, Colonel Abadie served as General Comptroller for the United States Shipping Board and Emergency Fleet Corporation. On May 1, 1920, he was appointed General Agent, in Washington, for the International

Maritime Corporation, Tropical Steamship Corporation, and other shipping concerns. For several years previous to his death, he had been engaged in practice as a Consulting Engineer, with offices in Washington.

Colonel Abadie, due to the wide spread of the engineering field which he served, while maintaining headquarters in St. Louis, acquired an extremely wide circle of friends and business acquaintances. His Army experience and association with the Shipping Board, together with his experience as a Consulting Engineer in Washington, also contributed to his remarkable popularity. He was of a disposition to hold this. He concerned himself in public and organization affairs and was a forceful advocate of policies destined to better his profession, as well as raise the plane of his community.

Colonel Abadie was a member of the American Institute of Electrical Engineers, the American Society of Mechanical Engineers, the Society of American Military Engineers, the Engineer's Club of St. Louis, the Western Society of Engineers, the Society of Colonial Wars, the Military Order of Foreign Wars, the American Legion, the Congressional Country Club, and St. Margaret's Protestant Episcopal Church, in Washington, D. C.

Colonel Abadie was elected a Member of the American Society of Civil Engineers on June 1, 1920.

RALPH ELIJAH BROWNELL, M. Am. Soc. C. E.*

DIED JANUARY 29, 1928.

Ralph Elijah Brownell was born in Filmore County, Minnesota, on January 5, 1857. He received his primary education in the public schools, and was graduated from the Englewood, Ill., High School in June, 1874.

Mr. Brownell then entered the Department of Public Works of the Town of Lake (now a part of Chicago), Ill., with which he was connected in every branch of municipal work until January, 1880. During four years of this period he received instruction in Mathematics and Civil Engineering under the private tutelage of the Principal of the Englewood High School. From January, 1880, to January, 1882, Mr. Brownell was Assistant Engineer with the South Park Commission of Chicago and from January, 1882, to March, 1883, he held a similar position with the Grand Trunk Railway Company on reconstruction work throughout Michigan, which was followed by his acceptance of the position of Chief Engineer and Superintendent of Public Works of the Town of Lake.

In March, 1886, Mr. Brownell became a member of the firm of Eggleston, Mallette, and Brownell, which firm was engaged in general contracting for public improvements. He was the responsible head of this organization in the development of property in the suburbs of Chicago and in this capacity had charge of all engineering work and its various resultant problems. In September, 1894, he organized the Brownell Improvement Company of Chicago, of which he was, successively, Vice-President, President, and again, Vice-President. This Company was engaged in subdividing and improving vacant

* Memoir prepared from information on file at the Headquarters of the Society.

property in the suburbs of Chicago. In January, 1902, he was made Consulting Engineer for the City of Chicago, and in this position was engaged particularly in the design of stone-crushing plants and in public works.

In June, 1904, Mr. Brownell moved to Oklahoma City, Okla., where he organized and operated the O. K. Building and Construction Company, Contractors, engaged in public improvements, principally in concrete construction. From November, 1907, to May, 1909, he served as Consulting Engineer for Oklahoma City; from May, 1909, to May, 1911, as Chief Engineer of the Park Department, designing the Park System and constructing a 28-mile boulevard around the city; and from May, 1911, to November, 1914, he again served as Consulting Engineer for Oklahoma City. In November, 1914, he was appointed County Engineer for Greer, McIntosh, and Pottawatomie Counties in the State of Oklahoma, which position he retained until August, 1916, when he became District Engineer of the Portland Cement Association for Oklahoma, and was thus engaged until August, 1922. In this connection, Mr. Brownell was primarily instrumental in promoting the building of concrete roads throughout the State.

Mr. Brownell first went to Los Angeles, Calif., in 1922, with the Rotary Club of Oklahoma City, and immediately became interested in the development of The Palos Verdes Estates, near Redondo Beach, Calif., planning and building the water-works for that organization. His death occurred while he was actively engaged on this construction.

He was a member of the American Association of Engineers, having served as President of the Oklahoma City Chapter. He was also a member of the Redondo Beach Rotary Club, and a Trustee of the Methodist Episcopal Church at that place, actively associated in its Sunday School work.

A man of impeccable character and of true fineness of nature, Mr. Brownell was loved and respected by all those of the Engineering Profession by whom or with whom he had been employed or associated.

On October 31, 1878, Mr. Brownell was married to Lucy T. Adams, who, with four daughters, survives him.

Mr. Brownell was elected a Member of the American Society of Civil Engineers on November 9, 1920.

LUTHER HAROLD BURT, M. Am. Soc. C. E.*

DIED JANUARY 29, 1929.

Luther Harold Burt was born on February 29, 1876, in Hartford, Conn., the eldest of seven children. His father, Luther W. Burt, was for many years in private practice as a Surveyor in Hartford, and for some time served as City Surveyor, so that the boy grew up in an engineering atmosphere. His mother, Mary A. Greene, of Middletown, Conn., and all his ancestors were of pure New England stock.

After receiving the usual preliminary education, principally in the Hartford Public Schools, he was graduated in 1900 from Trinity College, Hartford, with the degree of Bachelor of Science.

* Memoir prepared by Henry R. Buck and Robert J. Ross, Members, Am. Soc. C. E.

Following vacation work which began in 1895 with his father's field parties on various surveys and on the construction of the Springfield Branch of the Central New England Railway, Mr. Burt, in August, 1900, entered the employ of the Central Railway Company of New Jersey. He was successively Draftsman and in charge of a field party on maintenance of way for this Company, the Lehigh Valley, the Greenwich and Johnsonville, and the Pittsburgh and Lake Erie Railway Companies. For the latter, he was Draftsman and Designer in the office of the Chief Engineer on various structures connected with double- and four-tracking.

From March, 1903, to October, 1908, Mr. Burt was Draftsman and in charge of design under the Division Engineer of maintenance-of-way work for the Pennsylvania Railroad Company, at Philadelphia, Pa. The masonry design for the Delaware River Bridge above Easton, Pa., and the design of the West Morrisville Yard for the Pennsylvania Lines were among the larger items of his work during this period. Through the winter of 1905-06, he was Draftsman on the Electric Zone Improvements for the New York Central and Hudson River Railroad Company, and from March, 1906, until April, 1911, he was an Assistant Engineer for the Bronx Valley Sewer Commission, at White Plains, N. Y., in charge of important parts of the design and construction of large trunk sewers and other structures connected with the improvement of the Bronx Valley.

In April, 1911, Mr. Burt returned to Hartford and associated himself with his father, under the firm name of L. W. Burt and Son. After his father's death in 1921, he continued alone in the practice of surveying and general engineering. He designed and supervised the erection of the Brazos Dam at Middletown, as well as the Baldwin-Ives Dam, and was in charge of many of the real estate sub-divisions in and about Hartford. He had systematized the records of his father's early work, and not only made great use of them in his work of re-establishing old land lines, but was generous in allowing others to use them.

Mr. Burt was a regular attendant at the meetings of the local engineering societies and was well liked by his associates and by all with whom he came in contact. His death removes an engineer who was a credit to the profession and a worthy citizen.

He was married on April 7, 1903 to Claudia La Seur, of Schuylerville, N. Y., who survives him. Their only son, Richard White Burt, was associated with his father for some time and now carries on the work of the office under the old firm name.

Mr. Burt was elected an Associate Member of the American Society of Civil Engineers on November 1, 1910, and a Member on April 2, 1913.

EDWARD ZANE COLLINGS, M. Am. Soc. C. E.*

DIED NOVEMBER 19, 1928.

Edward Zane Collings was born on a ranch near Beaver City, Nebr., on December 12, 1885. He was graduated from the High School of Beaver City

* Memoir prepared by Sherman A. Jubb, M. Am. Soc. C. E., and W. T. Collings, Jr., Assoc. M. Am. Soc. C. E.

in 1902 and entered the State University of Nebraska the same year, taking a course in Civil Engineering. Circumstances prevented his completing the course, however, and, in 1905, he moved to California.

Mr. Collings began his practical engineering experience with the City Engineer of Santa Monica, Calif., following a short period spent with the Los Angeles and Salt Lake Railroad Company. In 1906 he moved to Los Angeles, Calif., where he entered private practice with Mr. F. D. Lanterman on subdivision work. This engagement was not of long duration.

Subsequently, he entered the service of the City of Los Angeles and, with the exception of a short period of absence, he remained in this service until the beginning of the World War in 1917. During this association Mr. Collings advanced rapidly through the stages of Draftsman and Grade Computer in the office, and of Instrumentman, Chief of Party, and Assistant Engineer in the field. He had charge of the surveys for the annexation of the Towns of San Pedro and Wilmington to the City of Los Angeles, and was the first Harbor Chief Surveyor when the initial parties were put in the field by the Harbor Department after the annexation. The field surveys of the present triangulation system covering the Harbor District were made under his supervision. In fact, he was one of the first of the City's engineers to pioneer in the development of Los Angeles Harbor. Many of the present pier-head lines, wharfs, and municipal docks were established during his service as Harbor Surveyor. He was greatly interested in water-front work of all kinds and during his leisure he studied navigation and obtained a navigator's license.

As Civil Service Assistant Engineer, Mr. Collings established and operated a rock quarry on Catalina Island for the Los Angeles Harbor Department, the quarried rock being transported and used in jetty construction.

While in college Mr. Collings had had military training which stood him in good stead when the United States entered the World War. Being an officer in the Reserve Corps, he was one of the first to register at the Presidio at San Francisco, Calif., and to become a Captain in the 316th Engineers, 91st Division, stationed at Camp Lewis, Washington. It was in the Battle of the Argonne, and while in command of his Company, that he was severely wounded. Eventually he lost one of his legs after spending three years of suffering in a hospital in an attempt to save it. Captain Collings was cited for bravery in action and recommended for a Majority. After the Battle of the Argonne, his wound resulted in disablement as far as the Army was concerned.

Army hospital experience cost Mr. Collings dearly, necessitating inactivity in his profession. Returning to Los Angeles, in 1921, he was reinstated with the City of Los Angeles as a Designing Engineer in the Street Planning Division. In this capacity he remained until the summer of 1923. Being recognized as proficient in this class of work, the Strong and Dickinson Syndicate of Los Angeles employed him as Chief Engineer on municipal subdivision and street improvements, and as such he served that Company under a Deputyship of the City Engineer's Office. The subdivision, planning, and improvement of the Morena Highlands and Silver Lake Terrace Tracts are monuments to his engineering ability. Engaged for a period of more than

six years with the same firm, he became recognized as an authority on city planning and development.

For three years previous to his death, Mr. Collings served as President of the Northwest Chamber of Commerce in the City of Los Angeles. In this capacity, he was most active in the development of the northwest section of the city and in addition was a leader in civic affairs. Mr. Collings' death resulted directly from an operation which he underwent with the hope of being restored to better health.

Mr. Collings was married, in 1906, to Elsie Verna Dakan, formerly of Beaver City, Nebr., whom he had known from childhood. His widow, one son, and two daughters survive him.

The achievements of Mr. Collings, particularly for the time dating from his discharge from the Army, are noteworthy, considering his physical handicap. During those years and until the time of his death, although suffering almost constant pain, he was ever active. Civic, political, and military organizations demanded much of his time. He was active among World War Veterans, and was Commander of the Disabled Emergency Officers of the World War and a member of the Sunshine Post of the American Legion. He was also a member of the First Presbyterian Church of Glendale, Calif., and keenly interested in all its affairs. Genial in disposition, a loving father and friend, he will be missed by all who ever knew him or worked with him.

Mr. Collings was elected a Member of the American Society of Civil Engineers on March 7, 1921.

GEORGE BIRDSALL CORNELL, M. Am. Soc. C. E.*

DIED MARCH 14, 1929.

George Birdsall Cornell was born in New York, N. Y., on October 17, 1855, the son of Birdsall Cornell who founded the old Cornell Iron Works and served as its head for a number of years. His family came to America in 1638 from England and first settled on Long Island.

Mr. Cornell received his early education abroad, attending private schools in Switzerland and France, and preparing for college at Anthem's School in New York. He was graduated from Columbia College, New York, in the School of Mines, in 1877, with the degrees of Engineer of Mines and Civil Engineer.

Mr. Cornell began his professional career as Rodman with the Engineer Corps of the Manhattan Elevated Railway Company, and in 1879 was Assistant Engineer on the construction of the Brooklyn Elevated Railway. From 1880 to 1882 he served as Engineer on the location and construction of the Buffalo, Rochester, and Pittsburgh Railway in Pennsylvania. Subsequently, he was engaged for two years as Bridge Engineer with the late Walter Katté, M. Am. Soc. C. E., during the construction of the New York, West Shore, and Buffalo Railway.

* Memoir prepared by H. J. Cornell, Esq., New York, N. Y.

In 1884 he became Chief Engineer for the Brooklyn Elevated Railway Company, during the time of the construction and equipment of its lines for operation. Mr. Cornell was then employed as Chief Engineer of Construction for the Union Elevated Railway Company, Brooklyn, N. Y., until 1889, when he went to Chicago, Ill., as Chief Engineer on the construction of the Chicago South Side Elevated Railway. He returned to New York in 1892, as Chief Engineer of the J. B. and J. M. Cornell Iron Works, engaged on what was, at that time, high building construction.

During the period extending from 1893 to 1895, Mr. Cornell was Chief Engineer for the East River Bridge Company and prepared the plans for a bridge on the site of the present Williamsburgh Bridge, obtaining the approval for this undertaking from the War Department. In 1895, he again took up the duties of Chief Engineer for the Brooklyn Elevated Railway Company and of Chief Engineer and General Manager for the New York and Brooklyn Bridge Railway Company, in which capacity he was in charge of the operation of bridge trains. He prepared and obtained the approval of plans for the elevated railway to cross the East River Bridge, and put these lines in operation. He also installed the first electric train service on the Brooklyn Elevated Railway. In 1898, Mr. Cornell went to Europe to investigate automobile designs for New York capitalists.

He was engaged on consulting work, from 1899 to 1903, reporting on water power, railway, and electrical developments in the United States and abroad. Among other projects was one for building an elevated railway along the route of Regents Canal in London, England. In 1904, he again was called abroad to report on electrical problems in France and Germany for international bankers.

Returning to the United States, Mr. Cornell, in 1905, made a reconnaissance for a railroad from Quebec, Que., Canada, to the French River, covering the entire route in winter on snowshoes. In 1906, he went to Cuba, to report on electrical and power properties for Cuban bankers and sugar interests and from 1906 to 1907 he was employed as Chief Engineer with the Memphis Street Railway Company, and as Resident Engineer for Ford, Bacon, and Davis, covering construction and reconstruction of railway, power plant, and overhead lines. In 1908 he became Chief Engineer for Meikleham and Dinsmore which firm he served until 1914 in charge of the design and construction of steam and hydro-electric plants, high-tension transmission lines, and electric railways in New York, New Jersey, and Pennsylvania.

From 1914 to 1918, Mr. Cornell was engaged in the supervision of power plants and distribution systems and was also associated with J. C. Brackenridge, M. Am. Soc. C. E., on the valuation of public utilities and steam railroad properties for the Cities of New York, Jersey City, N. J., Hoboken, N. J., Buffalo, N. Y., Little Falls, N. Y., and others. From 1918 to 1921 he served with Ford, Bacon, and Davis, first as Resident Engineer on a marine boiler plant at Richmond, Va., for the U. S. Shipping Board. He later acted as Engineer of Design of the factory and laboratory for the Pathé Company and as Valuation Engineer on properties of the Public Service Corporation of New Jersey and of other public utilities.

From 1921 to 1924, Mr. Cornell was again associated with Mr. Brackenridge on plans for the station of the Hudson and Manhattan Railway Company at West Side Avenue, Jersey City, and on testimony before the Public Utilities Board of New Jersey for Jersey City. He also designed the station at Ridgefield Park, N. J., for the New York, Susquehanna, and Western Railway Company, and offered testimony before the Public Utility Commission of New Jersey for the Town of Ridgfield Park. In behalf of adjacent property owners, he assisted in the valuation of the 42d Street Spur of the New York Elevated Railways, looking to its removal, and from 1924 to 1926 was engaged in the valuation of the Yonkers Electric Light and Power Company, and of the New York Edison Company for Murray and Company. The following year he was employed on the valuation of the property of the Philadelphia Electric Company for Gillette and Malcomson.

Mr. Cornell retired from active practice in 1928 after fifty-one years of varied and successful achievements in the Engineering Profession. He was a member of Psi Upsilon Fraternity and a Thirty-second Degree Scottish Rite Mason.

On January 31, 1882, he was married to Eleanor Jackson, of Ridgway, Pa. He is survived by a daughter, Mrs. James B. Tailer and five sons, George B., Jr., Harold Jackson, Robert Leslie, Thomas Whilehead, and Francis Shepard Cornell.

Mr. Cornell was elected a Junior of the American Society of Civil Engineers on August 6, 1879, and a Member on October 6, 1886.

RICHARD AUGUSTUS HALE, M. Am. Soc. C. E.*

DIED DECEMBER 17, 1928.

Richard Augustus Hale, the son of Bernice Sargent Hale and Sophia Kidder Hale was born on December 3, 1852, at Lowell, Mass.

After graduating from the Lowell High School, Mr. Hale entered the office of the late Hiram F. Mills, Hon. M. Am. Soc. C. E., Hydraulic Engineer, in Boston, Mass. A few months later Mr. Mills was appointed Engineer of the Essex Company in Lawrence, Mass. Young Hale went with him as his Assistant and remained in this office until he entered the Massachusetts Institute of Technology in 1873.

He was graduated from the Massachusetts Institute of Technology in 1877 with the degree of Bachelor of Science in the Department of Civil Engineering. During his four-year course at "Tech", Mr. Hale continued to work during the summer months with the Essex Company, and after receiving his degree he returned to that Company with which he remained associated continuously. In 1886 Mr. Hale was made Chief Assistant Engineer of the Company; when Mr. Mills died on October 4, 1921, he was made Engineer, in which capacity he served until his death.

Mr. Hale was an outstanding authority on water power and made several hundred reports on water-power sources in New England, New York, and

* Memoir prepared by Charles T. Main and Arthur T. Safford, Members, Am. Soc. C. E.

Delaware. He served as Chairman of the Commission appointed by the Court to investigate and define the water rights of various parties at Hinsdale, N. H., and made measurements for the proper sub-division of the rights involved in that controversy. He also served as an expert in many cases of water diversion where hearings were held before commissions and masters.

In 1894 he was appointed a member of the Lawrence Park Commission and served in that capacity for twelve years, being Chairman of the Commission during the latter half of his tenure of the office. He was a pronounced golf enthusiast and traveled about the United States, taking part in many tournaments on different courses.

Mr. Hale was a member of numerous clubs and organizations, including the Appalachian Mountain Club, the American Forestry Association, the Boston Society of Civil Engineers, which he served as President in 1916, the New England Water Works Association, the National Geographic Society, the American Civic League, the Massachusetts Civic League, the Merrimack Valley Technology Club, the Technology Club of Boston, the Merrimack Valley Country Club, the Lawrence Canoe Club, the Lawrence Boys' Club, and the Monday Night Club.

He was not merely a member of this long list of clubs, but one to whom membership meant service. His constant attendance at meetings of the different societies and his willingness to serve on committees, made him always outstanding. For this and his other winning qualities, Mr. Hale will long be remembered by his engineering associates, his neighbors, and his friends.

His was the unusual distinction of having worked for only one employer during his entire professional career, and that a long one. This includes not only his undergraduate days, but afterward, a single noteworthy service of more than fifty-one years. Few engineers can boast such a remarkable record.

On October 28, 1880, he was married to Arabella Johnson Plummer. Mrs. Hale, three sons, Frank B., Elliot K., and Richard A., Jr., and two daughters, Helen P. Hale and Mrs. Ernest A. Nordon, survive him.

Mr. Hale was elected a Junior of the American Society of Civil Engineers on February 6, 1884, and a Member on July 1, 1891.

CAREY VANDERVORT HODGSON, M. Am. Soc. C. E.*

DIED MAY 19, 1929.

Carey Vandervort Hodgson, the son of Lorenzo and Clara Emma (Hyatt) Hodgson, was born on July 11, 1880, at Wilmington, Ohio. He was educated in the public schools, at Wilmington College, and at Haverford College, Haverford, Pa. He received the degree of Bachelor of Science from Wilmington College in 1902, and from Haverford College in 1903.

* Memoir prepared by William Bowie, M. Am. Soc. C. E.

On March 31, 1904, he entered the field force of the United States Coast and Geodetic Survey with which he remained, except for two short periods, until his death. He was successively promoted to Assistant and then to Hydrographic and Geodetic Engineer, with the relative rank of Lieutenant Commander in the Navy (May 18, 1920). From December 18, 1905, to October 20, 1906, he was in commercial employment, and during the World War he served in the United States Army.

Under Executive Order of September 24, 1917, he was transferred to the Army with the rank of Captain in the Engineers Reserve Corps. His military service included the following: 1918, Topographical Officer (about 4 months) and commanding Company B (about 4 months), 104th Pioneer (sapper) Engineers, United States and France; Topographical Officer, 29th Division, and Assistant Division Engineer, France (more than 1 month); October, 1918, became Major, and for about 4 months commanded 2d Battalion 104th Engineers, France. By Executive Order of February 26, 1919, he returned to duty in the Coast and Geodetic Survey, reporting on March 19 of that year.

Major Hodgson had a very wide experience in charting and mapping work with the United States Coast and Geodetic Survey, during the twenty-five years he was connected with that Bureau. When he first entered the Survey he was assigned to one of its vessels, the *Matchless,* engaged on the hydrographic survey of the Potomac River; later, he was assigned to the *Blake,* operating on the New England Coast. He then had a season of topographic work along the Potomac River and, subsequently, returned to ship duty. This work carried him to many points on the Atlantic and Pacific Coasts and along the coasts of Alaska, as well as to the Philippine Islands. During the earlier period of his duty in the Islands, he was in charge of a launch party surveying along the coasts of Bohol, Cebu, Leyte, and Samar. The work included the original survey of the San Juanico Straits. Later, he commanded the Coast and Geodetic Survey Steamer, *Research,* which was engaged on surveys on the southern coast of Masbate.

After serving three years in the Philippines (1908-11), he returned to the United States and was assigned to the determination of telegraphic longitudes in the United States and in Alaska, in co-operation with the late Edwin Smith, M. Am. Soc. C. E., then an assistant in the Coast and Geodetic Survey.

In 1912, the Director of that Bureau decided that an attempt should be made to complete in a single season an arc of first-order triangulation, running approximately along the 104th Meridian from the vicinity of Pike's Peak, Colorado, to the Canadian boundary. This triangulation was needed to furnish strong geographic positions at the international border on which the boundary surveys could be based. Major Hodgson was chosen as Chief of one of the two triangulation parties, engaged on that work. He had had previous experience on second-order triangulation in the Philippines, and the reports of his superiors showed that he had accomplished the work assigned to him in an efficient manner. It was for this reason that he was selected for work on the 104th Meridian.

Plans were perfected in the Washington Office and the two Chiefs of Party took the field early in the summer. During a period of seven months they

completed an arc of triangulation 720 miles in length. This was rapid progress, but the work was done with standard accuracy and at low unit cost.

Major Hodgson's next assignment consisted of first-order triangulation and astronomic determinations of latitudes. In 1914, he was engaged for more than seven months in the determination of such latitude in Texas, New Mexico, Arizona, California, and Nevada. During the season of 1913, he used a 1½-ton automobile truck to transport his party from station to station while on astronomical work. This was the first time that the Coast and Geodetic Survey had used an automobile truck in its surveying operations. During 1912, an engineer of the Bureau had hired a truck for use while measuring some base lines along the 49th Parallel, in connection with the United States-Canada Boundary Survey. That officer had been assigned to the Boundary Commission to carry on base-line operations. The truck proved so successful on the boundary work that it was decided to use it as an experiment on the work that Major Hodgson had under his direction in 1913. The test was so successful that the truck became the standard means of transportation for geodetic surveying parties.

From 1914, until he entered the Army in 1917, he was engaged on various triangulation and traverse projects. On his return to the Survey, at the close of the World War, he was placed in charge of the first-order triangulation party working on what was called the El Reno (Okla.)-Needles (Calif.) arc of triangulation. This arc crosses the States of Oklahoma, Texas, New Mexico, and Arizona. After one season on this work, he was given, in May, 1920, the assignment of Assistant Chief of the Division of Geodesy, on duty at the Washington Office of the Survey. He occupied this position at the time of his death.

While serving as Assistant Chief of the Division of Geodesy, Major Hodgson had direct charge of the field force of the Geodetic Branch of the Survey. He made annual inspections of the geodetic parties in the field and prepared the instructions under which the work was done. He studied carefully the practices of other countries as shown in the official reports received from geodetic organizations abroad. He prepared the copy for two manuals of the United States Coast and Geodetic Survey, "Manual of First-Order Triangulation",* which appeared in 1926, and the other, "A Manual of Second and Third-Order Triangulation and Traverse",† which was issued about the time of his death.

While at the Washington Office, Major Hodgson took an active part in engineering matters. In addition to his official duties, he became a member of the American Military Engineers, and the Washington Society of Civil Engineers. He was also a member of the American Geographical Society, the Washington Academy of Sciences, the Philosophical Society of Washington, and a Fellow of the American Association for the Advancement of Science. He was a Director of the Washington Society of Engineers in 1927 and 1928, and also a Director, from 1927 to 1929, of the Society of American Military

* *Special Publication, No. 120,* U. S. Coast and Geodetic Survey.
† *Special Publication, No. 145,* U. S. Coast and Geodetic Survey.

Engineers. Since March 2, 1914, he had been a member of the Cosmos Club, of Washington, which may be called the scientific headquarters of the city.

On the organization, in December, 1926, of the Division of Surveying and Mapping of the Society and the election of an Executive Committee of that Division, Major Hodgson was appointed Secretary to the Committee. He served in that capacity until his death. He took an intense interest in the affairs of the new Division and helped to organize a number of standing and special committees formed to report on different phases of surveying and mapping. It may well be said that the success of the Division of Surveying and Mapping is due, in a great extent, to the efforts and ability of Major Hodgson. He represented the Chairman of the Division at the meeting of the Committees on Technical Procedure of the Society, held in Dallas, Tex., in April, 1929.

Major Hodgson and his 10-year old son, William Hockett, an only child, were drowned Sunday, May 19, 1929, while canoeing along the shore of Chesapeake Bay, in the vicinity of Annapolis, Md. He and his wife and son were spending the week-end at their cottage at Bay Ridge, about four miles south of Annapolis. He decided to test his canoe under sail during the forenoon of the day of his death. The canoe had been used by him and his son for the last two years, but had never before been equipped with a sail. No one saw the accident, but it is believed that the rather fresh wind carried the canoe from smooth water out into the increasingly rough waters offshore and made return from the capsized craft impossible, against the rising wind and sea.

In the early afternoon a search was made for the canoe and its occupants by an airplane, a submarine chaser, and launches stationed at the Naval Academy at Annapolis. The search was continued until dark and was resumed at daybreak, Monday. No trace whatever was discovered until the canoe was found, the following Wednesday, floating upside down, Major Hodgson's body under it, with the painter of the boat wrapped around his arm several times. His son's body was not recovered until June 2, 1929 (two weeks after the accident). It was found across the Severn River from Annapolis, twenty miles or so from where Major Hodgson and the canoe were found. Major Hodgson was buried, with full military honors, in Arlington National Cemetery, on May 25, and on June 3 the boy's body was buried beside that of his father.

Major Hodgson was married on April 17, 1916, to Edith Hockett, of Westboro, near Wilmington, Ohio, who survives him.

Due to his writings, his activities in engineering societies, and his administrative duties in the Coast and Geodetic Survey, Major Hodgson was recognized as one of the leading engineers of the United States in the field of surveying and mapping. He was considered an outstanding authority in these lines. In addition to his high professional qualifications, he possessed a personality and character that impressed most favorably all with whom he came in contact and endeared him to many. His untimely death is a great loss not only to the Government Service, but to the entire Engineering Profession.

Major Hodgson was elected a Member of the American Society of Civil Engineers on November 25, 1919.

RALPH HILLS HOWARD, M. Am. Soc. C. E.*

DIED SEPTEMBER 20, 1928.

Ralph Hills Howard was born in Zanesville, Ohio, on August 15, 1870, the son of Caleb Baxter Howard and Violetta Howard.

After completing his high school education and special study in civil engineering under the late Edmond Turner, M. Am. Soc. C. E., he entered railway service in October, 1889, as Draftsman with the Cincinnati and Muskingum Valley Railway Company. Until April, 1901, Mr. Howard served successively as Draftsman, Assistant on Engineering Corps, and Chief Clerk to the Engineer, Maintenance of Way. He designed and had direct supervision of the construction of masonry for replacing wooden, with steel bridges, and of the construction of a terminal yard, car repair and machine shops, and an engine house at Lancaster, Ohio.

In April, 1901, Mr. Howard went to Pittsburgh, Pa., as Assistant on the Engineering Corps of the Pennsylvania Lines West of Pittsburgh, where he was engaged on maintenance and construction work. In July, 1902, he was transferred to the St. Louis Division of the Vandalia Railway as Assistant Division Engineer in charge of maintenance and construction. In April, 1905, he accepted service with the Chicago and Eastern Illinois Railroad Company as Principal Assistant Engineer in charge of construction and improvements, and in October of the same year, he was promoted to the position of Engineer, Maintenance of Way, in direct charge of all maintenance and construction work.

From May, 1910, to January, 1911, Mr. Howard was engaged on special work in connection with railroad properties for Eastern capitalists, and from January to June, 1911, he was Chief Engineer of the Great Southern Lumber Company and Engineer, Maintenance of Way, of the New Orleans Great Northern Railway Company in charge of construction and maintenance. In June, 1911, he was appointed General Manager of the New Orleans Great Northern Railway Company, remaining in this position until May, 1915, when he was appointed Chief Engineer, Maintenance of Way, of the Wabash Railway Company, with headquarters in St. Louis, Mo. In October, 1923, Mr. Howard was appointed Chief Engineer of the Company, which position he held at the time of his final illness.

Mr. Howard was a man of sterling character, and of a very pleasant personality, highly regarded by every one with whom he came in contact. He had a host of friends, who loved and admired him, and who will miss him greatly. He was possessed of unusual ability as an executive, and a great capacity for organizing and advancing large projects to a successful conclusion. His sympathetic understanding of the problems of his subordinates enabled him to develop efficient and capable men in his organization. The engineers who were associated with Mr. Howard were indeed fortunate. No matter what circumstances arose, even in the midst of some perplexing

* Memoir prepared by W. S. Hanley and S. M. Smith, Associate Members, Am. Soc. C. E.

construction problem or catastrophe from flood, Mr. Howard always possessed a tranquil mind which made his decisions accurate and effective. He was an indefatigable worker and carried with him into his work a zeal and enthusiasm which was contagious and which permeated his entire organization.

Although Mr. Howard had not been in the best of health for several months prior to his last illness, he had still remained active. It was during his vacation at Petosky, Mich., that he was stricken with cerebral hemorrhage, and although he rallied from the first attack, he passed away on September 20, 1928. He was laid to rest in Woodlawn Cemetery, at Zanesville, Ohio, on September 24, 1928.

Mr. Howard was married on May 18, 1897, to Sina Larzelere, the daughter of William G. Larzelere, an influential and respected citizen of Zanesville, and a veteran of the Civil War. While blessed with no children, Mr. Howard's home life was ideally happy; he was always devoted to his wife and home.

He was a member of the Protestant Episcopal Church, and, as a boy, sang in the vested choir in the church at Zanesville. He was interested in sports and was an enthusiastic golfer, this being practically his only diversion from his work. He was a member of the American Railway Engineering Association, the Glen Echo Country Club, and the Missouri Athletic Club of St. Louis.

Mr. Howard was elected a Member of the American Society of Civil Engineers on July 2, 1913.

WALSTAN EMILE KNOBLOCH, M. Am. Soc. C. E.*

DIED JUNE 3, 1929.

Walstan Emile Knobloch was born on St. Bridgette Plantation, the family home, in Terrebonne Parish, Louisiana, on December 10, 1862, the only son of Judge Arthur F. and Amelia (Thibodaux) Knobloch. His maternal grandfather, Henry Schyler Thibodaux, was the founder of the Town of Thibodaux, La., and, at one time, served as Governor of Louisiana.

In Mr. Knobloch's early childhood, the family moved to Thibodaux where, as a boy, he attended Thibodaux College, later entering Tulane University, at New Orleans, La., from which he was graduated in 1883. At the time of his graduation he received a gold medal for his proficiency in mathematics.

In order to gain experience, Mr. Knobloch served with the Louisiana State Board of Engineers, without remuneration, from October, 1884, to February, 1886. Subsequent to this time he was engaged as follows: From February to October, 1886, as Computer in the United States Surveyor General's Office, and from October, 1886, to March, 1887, as Recorder in the United States Engineer Office at New Orleans; from March to May, 1887, as Leveler for the Texas and Pacific Railroad Company; from May to September, 1887, as Transitman with the U. S. Engineers, at New Orleans; from November, 1888, until

* Memoir prepared from information on file at Society Headquarters.

May, 1889, as Resident Engineer on the Costa Rica Railway, having had charge from December, 1888, to May, 1889, of the construction of the Eastern Division of this road, which included the design of all iron bridges on the line; from May, 1889, to August, 1892, as Resident Engineer on the New Orleans and Northwestern Railway, Assistant Engineer on the construction of the Natchez Sewer, Supervisor of Tracks on the Louisville and Nashville Railroad, Transitman on the survey of the Sabine and Marshall Railroad, and, also, Transitman on the survey of the Georgia, Tennessee, and Illinois Railway.

In August, 1892, Mr. Knobloch again entered the employ of the Federal Government in the U. S. Engineer Office, at New Orleans, as Surveyor in the Fourth Mississippi River District, his duties consisting of staking out and supervising the construction of levees from Red River Landing to New Orleans. In May, 1900, he was promoted to the position of Junior Engineer Superintendent in responsible charge of all levee work and of hydrographic surveys in the same District. In July, 1902, Mr. Knobloch was given additional charge of the improvement of the Amite, Bayou Manchac, Natabany, Tickfou, and the Tchefunct Rivers, and of the survey and construction of that part of the Intercoastal Canal, which is in Louisiana.

Continuing his work with the U. S. Engineer Office, he was advanced to the position of Superintendent. In 1923, while thus engaged, Mr. Knobloch suffered a stroke of paralysis and, on account of continued ill health, was forced to resign in 1926. He moved to his home in Thibodaux, where he resided with a sister, Fanny Knobloch, until his death on June 3, 1929. Mr. Knobloch never married.

In connection with his work with the Mississippi River Commission, Mr. Knobloch was considered to be one of the most competent and best-informed engineers in that service. He was an expert at levee construction and one of the first advocates of building levees by machinery. It was through his efforts that the use of such construction was extended through the Mississippi Valley below Vicksburg, Miss. His ability in forecasting river stages was almost uncanny, and in critical emergencies during flood periods his judgment many times saved a situation that seemed hopeless.

As a man, Mr. Knobloch was exceedingly modest and like many others his ability and achievements were little known beyond his own circle of intimates. His loss is deeply deplored by his fellow engineers and by others who knew him as a faithful and conscientious worker and a sincere friend.

Mr. Knobloch was elected a Member of the American Society of Civil Engineers on October 2, 1907.

* LOUIS RANDOLPH McLAIN, M. Am. Soc. C. E.*

DIED JANUARY 9, 1926.

Louis Randolph McLain was born at Washington, D. C., on March 13, 1846, the son of the Rev. William McLain and Mary (Mosby) McLain. His early education was obtained in the schools of Washington, the home of his

* Memoir prepared by R. F. Smith, Esq., Miami, Fla.

parents. Later, he entered Hamilton College, Clinton, N. Y., with the Class of 1865, but left at the expiration of his Junior year.

Mr. McLain's first engineering assignment was in December, 1869, when he entered the service of the South Trans-Continental Railroad Company as Draftsman and Office Assistant. In 1870 he was made successively Rodman, Transitman, and Leveler, being engaged on preliminary surveys and location until the consolidation of that road and the Southern Pacific Lines under the name of the Texas and Pacific Railroad Company. Thereafter, until January, 1872, he was Resident Engineer for the Jefferson Division of the latter road, resigning to engage in railroad and other construction work, which continued until 1876. In March of that year he was made Resident Engineer of the New Orleans Pacific Railroad Company, remaining in charge of construction until suspension of the work in June, 1878. He then located and superintended the construction of the Kanomie Narrow Gauge Railroad from Bayou Bouf to Kanomie Landing, on the Red River, Louisiana.

Following its construction, he operated the road until January, 1879, when he resigned to become Assistant United States Engineer of South Pass Jetties, at Port Eads, La. On the completion of this work in August, 1879, he was engaged as Assistant in the improvement of the James River, Virginia. Later, in March, 1880, he was made Resident Engineer for the Becharant and Clifton Forge Division of the Richmond and Allegheny Railroad, now a branch of the Chesapeake and Ohio Railroad.

This work being finished, Mr. McLain became Division Engineer of the Georgia Pacific Railroad Company, now that part of the Southern Railway System connecting Atlanta, Ga., and Birmingham, Ala. Thereafter, his activities were centered in Florida. In 1884, he was made Assistant Chief Engineer of the South Florida Railroad Company, now a part of the Atlantic Coast Line, running from Sanford to Tampa, Fla. When this road was completed in 1885, he was appointed Maintenance of Way Engineer, resigning two years later to enter the field of railroad construction, active at that time in the South.

During the next ten years, Mr. McLain constructed railway lines from Thomasville, Ga., to Montgomery, Ala.; from Thomasville, to Monticello, Fla.; from Savannah to Tybee, Ga.; and in addition a line from Savannah to Columbia, S. C., now a part of the Seaboard Air Line System.

In 1898, he turned his attention to hydraulic mining of pebble phosphate in Polk County, Florida, building, equipping, and operating successfully a plant, conceded by every one having knowledge of the industry, to be the most complete in Florida. Later, in July, 1903, these interests were sold to Savannah capitalists, representing the Peace River Phosphate Company.

Mr. McLain's retirement from active work followed the sale of his phosphate interests. He then opened an office as Consulting Engineer in St. Augustine, Fla., where he made his home, representing, among others, Belgian capitalists in the direction of their Florida mining enterprises until 1917.

Aside from his professional activities and mining enterprises, Mr. McLain maintained, from 1890 to 1920, a controlling interest in two banking institu-

tions in Florida and Alabama. The success of these, through a long period of years, was largely due to his sound judgment and wise leadership.

Mr. McLain was married on April 29, 1897, to Harriott Rutledge Ravenel, the daughter of Dr. St. Julien Ravenel and Harriott Horry Ravenel, of Charleston, S. C.

He was a member of the St. Augustine Golf Club, the St. Augustine Yacht Club, and the Commonwealth Club of Richmond, Va.

His long, useful life was characterized by thoroughness in the discharge of every undertaking and a sensitive loyalty to his friends and the interests that he served.

Mr. McLain was elected a Member of the American Society of Civil Engineers on February 2, 1881.

FRANK MOBERLY, M. Am. Soc. C. E.*

DIED JULY 13, 1928.

Frank Moberly was born in Barrie, Ont., Canada, on July 19, 1845. Educated in both Canada and England, he was a student of law from 1861 until 1863. In 1864 he was the recipient of the First Class Military School Certificate.

Mr. Moberly's first engagement was from 1863 until 1866 in the Engineering Department of the Northern Railway Company of Canada. His work consisted of surveying and similar details; and during the latter part of this engagement he went with the late Sanford Fleming, M. Am. Soc. C. E., as Assistant on Construction of the railway from Picton to Truro, Nova Scotia, Canada. During these years he also served as an Ensign in the Second Administration Battalion on the Niagara Frontier in answer to Canada's first call for volunteers. He was later commissioned as Justice of Peace for the Northwest Territories and the District of Thunder Bay.

In 1867, Mr. Moberly was employed by the Chicago, Rock Island, and Pacific Railway Company on surveys and construction work throughout Western Iowa, but he left this Company in the summer of 1868 to join a location party on the Union Pacific Railway through Utah and Nevada, later being placed in charge of this party. During the winter of 1868 he was transferred to construction work in Weber Canyon, Utah, and remained on this work until its completion in the fall of 1869.

He entered the service of the Milwaukee, Manitowoc, Appleton and New London Railway Company, in the spring of 1870, in charge of location north of Milwaukee, Wis. He left this position in May of the same year to become Assistant Engineer on exploration of mountain passes for the Northern Pacific Railway Company through the States of Montana, Idaho, and Oregon. Returning to Canada in the fall of 1871, Mr. Moberly was made Assistant on the location of the Muskoka Junction Railway Company from Barrie to Atherly, Ont., Canada, and of the North Gray Railway Company from Collingwood to Meaford, Ont., Canada, leaving that position in May, 1871, to

* Memoir prepared from information on file at Society Headquarters.

take charge of the first exploration parties for the Canadian Pacific Railway Company from Fort Garry to the Howse and Yellowhead Passes. He also conducted exploration through the territory north of Lac La Bicho and through the Lake Dauphin Country which extended north of the Riding and Duck Mountains, all in Manitoba.

In 1872, he went to Ottawa, Ont., Canada, and accepted the appointment of Assistant to Mr. William Murdoch, of the Canadian Pacific Railway Company, who was outfitting a party to proceed to Fort William, Ont., Canada, to make the first survey and the first location of the Canadian Pacific Railway, from that point westward to Savanna, Ont., Canada, over which the road was subsequently built without alteration. This trip to Fort William was a decidedly adventurous one and entailed a hazardous journey over 200 miles of waterways from Duluth, Minn., down Lake Superior in an open boat. It was at this time that Mr. Moberly received the distinction of being awarded the Dominion Government Medal for the daring rescue of the passengers and the crew from the propeller, *Mary Ward,* which met with disaster in November, 1872, in Georgian Bay.

From this time until 1920, Mr. Moberly was active in the following pursuits: In 1875, he was engaged in making an exploration of the country from Gravenhurst to Lake Nipissing for the extension of the Muskoka Junction Railway; in 1876 and 1877, he located and built the Prince Arthur Landing and the Kaministiquia Railway to connect what are now Port Arthur and West Fort William; in 1878, he was Engineer of the Mineral Hill Silver Mine in Nevada; in 1879, Division Engineer with the Canadian Pacific Railway Company surveying and building the line from the mouth of the Nipigon River to the north end of Long Lake and then, in turn, from Long Lake to Missinaibi, Ont., Canada, which was later rebuilt by the Canadian Northern Railway Company; during the summer of 1880 he was engaged on the survey for the Newfoundland Government of a railway line from St. John, New Brunswick, to Harbor Grace, Newfoundland; in 1881 he took charge of the location and construction of the Pambina Mountain Branch of the Canadian Pacific Railway and, subsequently, became Chief Engineer of the Northern Pacific Junction Railway of Ontario; in 1882, he made an exploration, for the Canadian Pacific Railway Company, of the crossing of the South Saskatchewan River at the Elbow and of a line up the Red Deer River; in 1884, he took a contract for the grading of six miles of railroad eastward from the Pic River, which was followed by his accepting the appointment of Commissioner of Police by the Dominion Government, with jurisdiction over Ontario, and his being sent to restore order after the riots in Michipicoton, Ont.; and in 1887 he completed the railroad to Sault Ste. Marie, Ont., Canada.

In 1891, and extending over a period of five years, Mr. Moberly was engaged in various private undertakings. In addition, he made a survey of Collingwood Harbor for the Department of Railways and Canals of Canada, and was active also in the construction of the St. Lawrence and Adirondack Railway, as well as surveying and promoting an air line from Toronto, Ont., to Collingwood; in 1896, he went to Rossland, B. C., Canada, where he was engaged in prospecting east and west of Kootenay, and in part of the Yale

Districts, as well as on the construction of Red Mountain Railway into Rossland, and on the location of the Crows Nest Pass Railway, along the shore of Kootenay Lake. In 1900 he was employed with the Department of Lands and Works of British Columbia, having charge of one of two parties sent out by the Government to make surveys of passes through the Hope Mountains, which, to that time, had been considered impracticable for a railroad; in 1902, he made estimates for such a passage through these mountains and their boundary country and also plans for a railway to Dease Lake in Northern British Columbia; in 1903, he had charge of the construction of the Prince Albert Branch of the Canadian Northern Railway, from Erwood to Melfort, Sask., Canada; from 1904 to 1909, he was in charge of party on preliminary and location surveys for the National Transcontinental Railway Company, east of Cochrane, Ont., Canada, and along the north shore of Lake Abittibi extending eastward to the Harricanaw River; and from 1910 to 1912, he made explorations and reports on the capabilities of the great clay belt for the Chairman of the Temiskaming and Northern Ontario Railway Company.

In 1913, Mr. Moberly was appointed Assistant Engineer of the Department of Public Works of Canada, for which he had charge of the territory in the Midland District and also of that around Toronto. He later was made Acting District Engineer at Midland, and Barrie, Ont., which latter place he made his home after his retirement. Altogether, Mr. Moberly was in the service of the Government of Canada for about twenty-three years which period terminated in 1920, when he retired from active work. During this time he had practically explored the Dominion from coast to coast, opening it up for settlement, and making way for its widely expanding civilization.

Coupled with Mr. Moberly's professional services and experiences during the period extending from 1880 to 1915 was a definite and continuous service on his part in civil duty to the State. The following include some of his positions in this connection: Provincial Magistrate for the Province of Manitoba; Reeve of Neebin Municipality, District of Thunder Bay; Commissioner of Police under the Police Act of Canada for Ontario; and Commissioner under Peace Preservation on Public Works Act; Justice of Peace for the Province of British Columbia; Magistrate for the Province of Quebec; Police Magistrate for the District of Nipissing; Justice of Peace for the County of Simcoe; and President of the County of Simcoe Home Guard Rifle Association.

In 1874, Mr. Moberly was married to G. A. McIntyre, the daughter of John McIntyre, a Hudson Bay Officer at Fort William, Ont. Mrs. Moberly died in 1880, and, in 1882, Mr. Moberly was married to Mary McIntyre, a sister of his first wife, by whom, with two daughters and two sons, he is survived.

Mr. Moberly's entire life is an expression of pioneering in Canada when the Dominion's future was much less assured than it is to-day. To have been an explorer all his days, in itself, lends a glory and a romance to his name. He was a pioneer in the greater sense of the word, in that he did not settle on a small clearing of land and thereby establish a permanent comfortable home, but was ever blazing new trails in virgin country—leaving the secure

and certain to encounter the risk of the unknown. He surveyed railways, hunted criminals, started clearings, dug mine shafts, and endured the prairie winter in tents, ever measuring the uncalculated and keeping continuously in the forefront of civilization; this was his life. John F. Stevens, Past-President, Am. Soc. C. E., extends to Mr. Moberly and his associates the following tribute:

"The railways—indeed, civilization itself—owes a debt of gratitude to the pioneer engineers who blazed the way through trackless wildernesses to make homes for thousands who followed them."

Mr. Moberly was elected a Member of the American Society of Civil Engineers on October 7, 1903.

ROBERT VAN ARSDALE NORRIS, M. Am. Soc. C. E.*

DIED APRIL 20, 1928.

Robert Van Arsdale Norris, the only son of Thomas Braxton and Mary Latimer (Ruxton) Norris, was born in Newark, N. J., on May 2, 1864. He came of distinguished New England ancestry, being directly descended from Governor William Bradford, John Alden, and Timothy Dwight.

After a preparatory course in the Collegiate School of New York, N. Y., Mr. Norris entered the Columbia University School of Mines, and was graduated with the degree of Mining Engineer in the Class of 1885, a class that included in its membership a number of men who became distinguished in their professions. From among them, young Norris was selected as Assistant to Professor H. C. Munroe in the Summer School of Mining and Surveying, which engagement followed his graduation. In the latter part of 1886, after he had served a short time as an Inspector of dredging operations on the Maurice River, and in the Chemical Laboratory of Herman Behr, in Brooklyn, N. Y., he joined the Engineering Corps of the Susquehanna Coal Company, then owned by the Pennsylvania Railroad Company. Here he rose through sheer ability and hard work to the position of Chief Engineer in 1900, remaining until 1904, when he resigned in order to engage in private business as a Consulting Engineer. His judgment in making the venture proved sound, for he was eminently successful. Early in 1923 Mr. Norris took his son, Robert V. Norris, Jr., into partnership with him, under the firm name of R. V. Norris and Son.

That the exercise of sound judgment was such a characteristic of Mr. Norris as to pertain to the nature of a habit is attested by the fact that he was retained as Consulting Engineer by the Coal Department of the Delaware, Lackawanna and Western Railroad Company (afterward becoming an independent organization incorporated as the Glen Alden Coal Company), the Lehigh Valley Coal Company, Coxe Brothers and Company, Incorporated, the Coal Department of the Pennsylvania Railroad Company, the Wilkes-Barre and Hazleton Railroad Company, the Lehigh Coal and Navigation Company, the Sterling Salt Company, and other important interests.

* Memoir prepared by Edward W. Parker, Esq., Philadelphia, Pa.

Mr. Norris specialized in the examination and valuation of coal properties, his most important undertaking of this nature being probably the appraisal of the anthracite properties of the Pennsylvania Railroad Company, which eventuated in their sale, in 1915, to M. A. Hanna and Company, of Cleveland, Ohio, and the incorporation of the Susquehanna Collieries Company as the operating company for the Hanna anthracite properties. The year previous (1914), Mr. Norris had made a valuation report on six collieries of the Temple Coal Company. Other major, or valuation, reports made by Mr. Norris were on the properties of the Lehigh Coal and Navigation Company, in 1917; the bituminous coal properties of the Stonega Coal and Coke Company of Virginia and the Consolidation Coal Company of Maryland, in 1920; the bituminous coal lands of the Cambria Steel Company, in 1922; the anthracite properties of Madeira, Hill and Company and of the Hazle Brook Coal Company, in 1923; the anthracite properties of the Hudson Coal Company, Delaware and Hudson Company, Delaware, Lackawanna and Western Railroad Company, and Lehigh Valley Coal Company, in 1924; Coxe Brothers and Company, Incorporated, the Scranton Coal Company, and the Elk Hill Coal and Iron Company, in 1925; and the Jeddo-Highland Coal Company, in 1926. He also served as arbitrator in many cases involving complicated technical problems.

Mr. Norris was not only an engineer; he had a special gift in cost accounting, and, in co-operation with Col. R. H. Montgomery, of Lybrand, Ross Brothers and Montgomery, prepared a system of cost accounting for anthracite operators. His facility with figures approached the uncanny. It took him but a short time to familiarize himself with the fundamentals of the Federal Income Tax laws as applied to the involved technicalities of anthracite production, and he served as an expert for a number of companies before the Tax Authorities, in Washington, D. C.

During the World War, Mr. Norris was called to Washington to serve as an adviser to the War Industries Board on fixing prices for anthracite and bituminous coal. Later, in association with Cyrus Garnsey, Jr., and James H. Allport, M. Am. Soc. C. E., he served as a member of the Engineers' Committee of the United States Fuel Administration. He became "a-dollar-a-year" man and, giving up his own practice, rented a house in Washington and moved his family there. His two daughters, then unmarried, served as ambulance drivers.

In his busy career Mr. Norris found time to give to others the benefit of his own knowledge and experience. At various times he was a non-resident lecturer on coal mining, both at his Alma Mater, Columbia, and at Harvard Universities. The *Transactions* of the American Institute of Mining and Metallurgical Engineers have been enriched by many of his contributions. He was a Councillor of the Institute from 1908 to 1910, Vice-President in 1911 and 1912, and a Director from 1920 to 1927. He served on numerous committees at various times and was ever enthusiastic and tireless in his devotions to that which he felt was for the best interests of the organization.

In 1914, Columbia University conferred upon Mr. Norris the honorary degree of Master of Science and in 1920 he was the '89 Medallist. He was always active in the Alumni affairs of the University. In addition to membership in the American Institute of Mining and Metallurgical Engineers, Mr. Norris was a member of the American Society of Mechanical Engineers, and of the Canadian Institute of Mining and Metallurgy. He was a member of a number of clubs, which included the University and Engineers' Clubs of New York, and the Cosmos and Chevy Chase Clubs of Washington.

He is survived by his widow, Esther Wadhams (Shoemaker) Norris, one son, Robert V. Norris, Jr., of Wilkes-Barre, and two daughters, Mrs. Jane N. Zerbey, of Pelham, N. Y., and Mrs. Esther S. Triest, of New York.

It falls to the lot of relatively few men to attain so eminent a position in their profession as that achieved by "Van" Norris in his chosen profession—mining engineering, specializing in anthracite mining.

At the time of his death, and for some years prior thereto, Mr. Norris was generally recognized as the dean of the profession in the anthracite region. When important problems were to be solved, were it the fighting of a bad mine fire, like the recent one at the Woodward Colliery of the Glen Alden Coal Company; the valuation of coal-mining properties for purposes of sale, or for other reasons, such as that of the Susquehanna Collieries Company by the Pennsylvania Railroad Company to the M. A. Hanna interests; the arbitration of a serious dispute involving engineering problems; the adjudicating of complicated income tax matters with the Federal authorities, or ordinary tax controversies with the State and local officials—whatever the difficulty—Mr. Norris was the one selected for the job. His unimpeachable integrity, scientific training, wide experience, and sound judgment commanded the confidence of those in whose interests he served as well as the respect of his opponents.

A brief sketch of Mr. Norris' life published in a technical journal,* closes with the following words:

"An engineer of the highest rank, a man of the most upright character and of marked personality, he was held in high esteem by all who knew him, and his death at an age when he apparently had many more years of active public service before him will be deeply mourned."

This is indeed true; he is deeply mourned, and his profession lost a brilliant disciple when he passed away.

Mr. Norris was elected a Junior of the American Society of Civil Engineers on December 7, 1887, and a Member on March 5, 1902.

EBEN ERSKINE OLCOTT, M. Am. Soc. C. E.†

DIED JUNE 5, 1929.

Eben Erskine Olcott was born in New York, N. Y., on March 11, 1854. He was the second son of a family of four sons and four daughters, the children of John N. and Euphemia Helen (Knox) Olcott.

* *Mining and Metallurgy*, May, 1928.

† Memoir prepared by Professor Robert Peele, New York, N. Y.

After a preparatory training in the College of the City of New York, where his early interest in scientific and technical subjects manifested itself, Mr. Olcott entered the Columbia School of Mines, and was graduated therefrom in 1874 with the degree of Engineer of Mines. As a student, he stood high in a class that included among its members a group of young men who subsequently made their mark in professional life.

Immediately after graduation, Mr. Olcott began his field career as Chemist to the Ore Knob Copper Company, of North Carolina, where he was soon put in charge of the then well-known Hunt and Douglas process of copper extraction. In 1875, he was appointed Assistant Superintendent of the Pennsylvania Lead Company, Mansfield Valley, Pa. In 1876, he went to South America for the Orinoco Exploring and Mining Company, of Venezuela, and in 1878-79 served as Superintendent of the gold mines of this Company, near El Callao, Venezuela. Returning to the United States in the latter part of 1879, he spent two years in examining and reporting on mines in a number of the Western States. From 1881 to 1885 he was Superintendent of the St. Helena Gold Mining Company, Sonora, Mexico. On resigning this post, after four years of strenuous work under untoward conditions in the development of the property and erection of plant, he took up consulting practice, with headquarters in New York.

In 1886, Mr. Olcott was engaged for ten months in an elaborate examination of the Cerro de Pasco Copper District, in Peru. At the same time Mr. A. D. Hodges, Jr., a prominent mining engineer of Boston, Mass., made an independent reconnaissance. Their combined studies and recommendations furnished the basis upon which were founded, years afterward, the extensive operations of the present Cerro de Pasco Copper Company. Next, at the instance of groups of New York capitalists, Mr. Olcott headed two protracted prospecting expeditions to the gold fields of Dutch and British Guiana, and another to the Provinces of Tolima and Antioquia, in the Republic of Colombia.

In 1890-91, for the Peruvian Exploration Syndicate, of London, England, he examined and reported upon the gold and copper resources of the Sandia and Carabaya Districts of Eastern Peru. This was a task involving considerable difficulty and hardship, on account of the remoteness of the very sparsely populated regions traversed, the entire lack of modern means of transport, and the great altitude (reaching at least 17 000 ft.) of some of the terrain. After leaving the railway, south of Cuzco, the entire journey, occupying a number of months, was made on mule-back or on foot. Thereafter, for about ten years, he was actively engaged in professional work in Mexico, British Columbia, Ontario, New Brunswick, and various parts of the United States.

Mr. Olcott was a member of the American Institute of Mining and Metallurgical Engineers almost from its inception, having been elected in 1873 (while still a student), in the third year of the life of the Institute. For two years (1901-02) he served as its President, and, in 1901, attended a meeting of that body held in Mexico, delivering a Presidential Address in the City of Mexico, in the Spanish language, before a representative assembly of State officials and engineers.

Mr. Olcott's professional and business life of fifty-four years was rather sharply divided into two distinct periods. For the first twenty-one years he devoted himself solely to mining engineering and metallurgy, as outlined previously. Then, circumstances led him into a wholly new sphere of activity, very distantly related to the profession in which he had been trained by faithful study and long experience.

Following the death of his brother-in-law, Charles T. Van Santvoord, General Manager of the Hudson River Day Line, Mr. Olcott in 1895 accepted an appointment to the managership of that line of passenger steamers, running between New York and Albany, N. Y., which had been founded by his father-in-law, Commodore Alfred Van Santvoord. On the death of the latter, in 1901, Mr. Olcott was elected President and General Manager of the Company, which at that time was operating two steamers, the *Albany* and the *New York*. In the succeeding years, as traffic increased, new steamers were added, until at his death the fleet comprised the *Hendrick Hudson, Alexander Hamilton, Robert Fulton, DeWitt Clinton, Peter Stuyvesant, Albany* and *Chauncey M. Depew*.

In his management of the Day Line, Mr. Olcott exhibited his characteristic energy and resourcefulness. No detail that might contribute to the success of the business was too small to receive his personal attention. He made himself familiar with every feature of the boats, from the boiler and engine rooms to the Commissariat Department. His hours of work during the operating seasons were much longer than those of any employee. Unquestionably, his engineering training aided materially in achieving the success attending his control of the Company's large business.

During this second period of his career, he continued for a number of years to give part of his time, in an advisory capacity, to the affairs of the consulting engineering firm of Olcott, Fearn, and Peele, which was organized in 1896. Later (1901), the firm became Olcott, Corning, and Peele, and, finally, Olcott and Corning.

Mr. Olcott had a forceful, impressive personality. Among his outstanding characteristics were his integrity, large humanity, kindly courtesy, and never-failing helpfulness. These qualities secured the affection, loyalty, and respect of all who were brought into contact with him—employees and business associates alike.

His wide business and social interests and his sympathetic nature are indicated by the diversity of the large number of philanthropic, religious, and other organizations with which he was connected in various capacities. Of these, only a comparatively few can be mentioned here: Trustee of the American Seamen's Friend Society, and Treasurer and Trustee of the American Indian Institute; Vice-President of the Lincoln Safe Deposit Company and of the Evangelistic Committee of New York City; member of the Administration Committee of the Federal Council of the Church of Christ in America; member of the Advisory Committee, American Exchange-Irving Trust Company and of the Travelers' Aid Society; member of the Board of Managers, American Bible Society; member of the New York Chamber of Commerce, Merchants' Association, Metropolitan Museum of Art, New York Historical Society, Sons

of the Revolution, the American and New York State Forestry Associations, National Board of Steam Navigation, and the Board of Foreign Missions of the Dutch Reformed Church of America. He was also a member of the following New York clubs: Union League, Engineers', and the Down Town Association.

Mr. Olcott was married in 1884 to Kate Van Santvoord who, with three sons and one daughter, survives him. He died on June 5, 1929, after a long illness. His eldest son, Alfred, for years associated with him in the conduct of the Hudson River Day Line, has latterly been Vice-President and General Manager of the Line. One of his brothers, Judge William M. K. Olcott, was formerly District Attorney of New York.

Mr. Olcott was elected a Member of the American Society of Civil Engineers on July 5, 1893.

ROBERT STEVENS PARSONS, M. Am. Soc. C. E.*

DIED MAY 18, 1928.

Robert Stevens Parsons, the son of the Rev. Solomon and Louise (Towt) Parsons, was born in Hohokus, N. J., on May 26, 1873. He was prepared in Paterson High School for Rutgers University at New Brunswick, N. J., which he entered with a State Scholarship and from which he was graduated in 1895 with a degree of Bachelor of Science. Three years later he received the degree of Civil Engineer. As an undergraduate, Mr. Parsons' life was a most strenuous one and his days were occupied with numerous campus activities. He enjoyed the honor of being Captain in the Military Corps and of the football and track teams, as well as the further distinction of being a member of the Delta Upsilon Fraternity, and President of the Self-Governing Board and of his Senior Class.

Within a week of his graduation, Mr. Parsons entered the employ of the Erie Railroad Company as Chainman. From the very bottom rung of the engineering ladder, he worked up through all departments until he attained the position of Chief of Maintenance of Way, from which he transferred to the Operating Department as Superintendent. In this capacity, he greatly distinguished himself by handling a difficult strike. Continuing his upward climb he reached the position of Chief Engineer and, at length, Vice-President in charge of maintenance and operation.

Mr. Parsons was a Trustee of Rutgers University and one of a group that encouraged and strengthened athletic activities at the time when the Rutgers football eleven was greatly lauded among college teams. He was very active in civic work in the communities in which he resided, and during his term as Vice-President, when one of his duties was the building up of friendly relations between the communities and the railroad, became a well-known public speaker.

He was a member of the New York Railroad Club, the American Railway Engineering and Maintenance of Way Associations, and the New Jersey

* Memoir prepared by Floyd Y. Parsons, Esq., New York, N. Y.

Highway Commission, and was affiliated with the Masonic Lodge at Nutley, N. J., and the Rotary Club. He was also a Lieutenant in the New Jersey Militia and an Officer of the Military Reserve.

In 1897, Mr. Parsons was married to Eleanor Howse, of Paterson, N. J., and is survived by his widow and two daughters, Mrs. Robert Miller, of Nutley, and Mrs. Asel Adams, of Youngstown, Ohio.

"R. S.", as he was affectionately known, had a strong, dominant personality, and an army of friends ranging from the humblest trackmen to distinguished railroad executives. He was always cheerful, a marked optimist, and although frequently under the severest of strains, he was able to cheer and stimulate his subordinates. The following revealing remark comes from one of them: "How can we crab when 'R. S.' is around?"

It is remarkable that with this friendly relationship among his associates there occurred no decrease in efficiency and co-operation, these being two prime essentials that Mr. Parsons always demanded. He was a real man's man, loved by thousands, and his services were invaluable to his Company. In the words of the First Vice-President of the road is expressed the thought of his many friends: "I do not see how we are going to find one to replace him".

Mr. Parsons was elected a Member of the American Society of Civil Engineers on September 6, 1905.

JOB TUTHILL, M. Am. Soc. C. E.*

DIED DECEMBER 28, 1928.

Job Tuthill was born, of Puritan stock, in Blooming Grove, N. Y., on October 26, 1855, the son of Benjamin S. and Mary Elizabeth (Cooley) Tuthill.

He was graduated from the University of Michigan, at Ann Arbor, Mich., in 1883, with the degree of Bachelor of Science in Civil Engineering. He at once entered railway service as a Civil Engineer and continued actively in this work for the remainder of his life. His ability as a designer and builder of railway structures came to be widely recognized, chiefly through his work on the Pere Marquette Railway. He served this Company and its predecessor lines as Assistant Engineer, Bridge Engineer, Assistant Chief Engineer, and Chief Engineer, during a total of thirty-five years.

Mr. Tuthill was a constant and thorough student of engineering subjects. He took an active interest in the work of the various engineering societies of which he was a member, and gave liberally of his time to the work of their committees. He possessed, in full measure, the engineer's habit of mind, viewing his work as the fulfillment of a responsibility to his employers and his countrymen, to build safely and well, and to make proper use of, and conserve, Nature's materials. His conscience is reflected in the hundreds of well-designed and carefully executed structures standing as monuments to his faithful labor.

* Memoir prepared by the following Committee of the Detroit Section: Charles S. Sheldon, *Chairman*, J. F. Deimling, H. E. Riggs, Members, Am. Soc. C. E., Paul Chipman, Assoc. M. Am. Soc. C. E., and A. L. Grandy, Esq., Detroit, Mich.

His distinguishing quality was his fine character. He will be remembered for his gentlemanly, courteous manner toward his associates, his loyalty to his profession and his friends, his modesty, reticence, quiet speech, unbounded sympathy, and his charitable attitude toward human weakness or misfortune. He was ever ready to aid those in need of moral support or material assistance.

During his professional life many young men passed under his tutelage. These were uniformly influenced to their lasting benefit—in their attitude toward their work, by Mr. Tuthill's careful instruction, and, in their characters, by his fine example. In 1914, his College conferred upon him the Honorary Degree of Master of Engineering. Dr. Hutchins, in bestowing the degree, eulogized Mr. Tuthill as follows:

"A graduate of the University of Michigan, Department of Engineering, in the Class of 1883. Prominent as a builder of railway bridges and terminals, he has won praise for his work and respect for his modest manhood."

In 1884, Mr. Tuthill was married to Florence B. Craig, of Kalamazoo, Mich., by whom, with a daughter, Louise Kingsbury, he is survived. A son, Benjamin Sayre, died in 1910.

Mr. Tuthill was elected a Junior of the American Society of Civil Engineers on June 6, 1888, and a Member on October 4, 1893.

EDWARD CHARLES GERSBACH, Assoc. M. Am. Soc. C. E.*

DIED MARCH 3, 1929.

Edward Charles Gersbach was born in Montezuma, Iowa, on July 4, 1880, the son of Frank and Emma (Schell) Gersbach. His father was born in Germany, but came to the United States at an early age. His mother was a native of Iowa, although of German extraction. He received his primary education in the town of his birth, and went from there to Iowa State College, Iowa City, Iowa, from which he was graduated in 1904 with the degree of Bachelor of Science in Civil Engineering.

After completing his High School course, Mr. Gersbach commenced work in engineering lines as Chainman and Rodman, first for the Iowa Central Railway Company, and, later, for the Chicago, Rock Island, and Pacific Railway Company. While he was in college, he spent his vacation in 1901 as Instrumentman for the Chicago Union Transfer Company, and the following summer as Inspector on sewer construction for the same Company. During the summer of 1903 he was Transitman for the Logansport, Hammond, and Chicago Traction Company, and following his graduation in 1904 was employed with the Marshalltown Interurban Railway Company as Transitman. He then served as Draftsman for the American Bridge Company, at Ambridge, Pa., for several months and, later, as Instrumentman with the Indiana Harbor Railroad Company.

In the meantime, Mr. Gersbach had taken a Government Civil Service examination. He passed this and accordingly was appointed to the U. S. Reclamation Service in May, 1905. During the next three years, he served

* Memoir prepared by H. F. Robinson, Esq., Albuquerque, N. Mex.

in various capacities as Engineering Aid, Instrumentman, and Assistant Engineer. In January, 1907, he was in direct charge of the location and construction of 110 miles of lateral and waste ditches on the Huntley Project, in Idaho.

On being transferred to the Sun River Project, Montana, as Assistant Engineer, he had charge of the design and construction of concrete structures. In March, 1908, he was transferred to the Blackfoot Project, Montana, as Division Engineer.

In July, 1911, Mr. Gersbach entered the U. S. Indian Irrigation Service, where he was placed in charge of the construction of, and, later, the operation of, the Hogback Project on the Navajo Indian Reservation in Northwestern New Mexico. He retained this position until 1924, when he was transferred to work among the Rio Grande Indian Pueblos, with headquarters in Albuquerque, N. Mex., where he remained until his death.

His illness, which terminated fatally, was incurred in the line of duty. While he was engaged on instrumental work beside an open cut, he slipped, and, being a large man, injured one of the ligaments in his hip. Although he had the best of medical and surgical care, complications followed, resulting in his death on March 3, 1929. His body was taken to his old home in Montezuma for interment.

During Mr. Gersbach's engagement on the Hogback Project, in New Mexico, he met Olive Johnston, who at that time was a missionary nurse at an Indian school, and they were married on April 3, 1912. They had one son, Frank. In addition to his wife and son, his surviving relatives are his father, a brother, Otto Gersbach, of Chicago, Ill., and a sister, Mrs. Nellie Barteld.

Mr. Gersbach was a careful and skillful engineer, respected and liked by his associates—a man with a host of friends. He was a Mason, with his affiliations in Montezuma. His death is a distinct loss to his community and the Department of the Government in the employ of which he had served so many years.

Mr. Gersbach was elected an Associate Member of the American Society of Civil Engineers on June 1, 1909.

DAVID THOMPSON, Assoc. M. Am. Soc. C. E.*

DIED APRIL 29, 1929.

David Thompson was born in Philadelphia, Pa., on March 17, 1887. He was the son of David S. Thompson, a member of the Philadelphia Stock Exchange, and Mary (Taylor) Thompson, the daughter of John M. Taylor, a wholesale dry goods merchant of Philadelphia.

Mr. Thompson's early education was acquired in the public schools and High School of his native city, after which at the age of 17, he entered the University of Pennsylvania. He was graduated therefrom in June, 1908, with the degree of Bachelor of Science in Civil Engineering, and the marked distinction of being the youngest member in his class.

His first professional engagement was from 1908 to March, 1910, as Draftsman on the design of track elevation, etc., in the Grade Crossing

* Memoir prepared from information on file at Society Headquarters.

Division of the Bureau of Surveys of Philadelphia. During March of the same year, he served as Rodman with the New York Division of the Pennsylvania Railroad Company, at Jersey City, N. J.

Attracted by a higher salary, he accepted in April, 1910, a position with the Isthmian Canal Commission at Culebra, Canal Zone, Panama. He was assigned to the Construction Department and served as Inspector of Dredging, with the Division of Lock Design, and Draftsman on machinery equipment, until October, 1912.

Subsequently, Mr. Thompson was engaged in the following positions: From March to September, 1914, on inspection, construction, and installation of ice-making equipment and refrigeration for the Railway and Stationary Refrigerating Company (The Clothel Company), of New York, N. Y.; from April to October, 1915, on steel inspection under Mr. Lyddon, of the Inspection Office of the English Army, at Pittsburgh, Pa.; from January to March, 1916, with the R. H. Beaumont Company, of Philadelphia, as Draftsman on the design of elevating and conveying equipment; from March, 1916, to July, 1917, in the offices of the Chief Engineer and Assistant Engineer of the Pennsylvania Railroad Company, at Philadelphia, as Draftsman on design and track work; from August, 1917, to September, 1918, during the World War, with the Bureau of Yards and Docks of the United States Navy Department, at Washington, D. C., as Inspector on construction of armor plate and ordnance and projectile plants at Charleston, W. Va., and at the League Island Navy Yard in Philadelphia; and from September to December, 1918, with the Emergency Fleet Corporation of the United States Shipping Board, Department of Shipyard Plants, at Philadelphia, as Draftsman on the design of water pipe lines for fire protection. At this time, Mr. Thompson was compelled to give up active work on account of ill-health from which he had suffered ever since his residence in the Canal Zone. By January, 1925, he had recovered sufficiently to continue his professional career, and he accordingly accepted a position in the U. S. Engineer Office at Wilmington, Del., as Inspector on dredging work, where he continued until April.

The West seemed to attract Mr. Thompson and in May, 1925, he went to Los Angeles, Calif., where he was active in the City Engineering Department, as Junior Civil Engineer, on street improvements, paving, etc. At intervals, dating from 1912, Mr. Thompson was also engaged in private work.

At the time of his death he was again employed in Government work and was located at Hawthorne, Nev., as Associate Engineer with the U. S. Naval Ammunition Depot at that place. His death occurred, after a short illness, from pneumonia. He is survived by his mother, Mrs. Mary Taylor Thompson, and two sisters.

A gentleman of staunch character and high principles which were the outward expression of an intrinsic fineness of nature, and intensely interested in his profession during his entire career, Mr. Thompson was conscientious, capable, and dependable. He was an affectionate and devoted son, and was highly regarded by his teachers and loved by his classmates. The following tells but slightly of an affection for him which lasted through the years:

"I remember him as if it were yesterday, as we sat together our four years in college. During our association I became very fond of David, as he was a man of upright character and fine bearing and I feel it was a privilege to have been so close to him during that time."

He was a member of the Methodist Episcopal Church. He had joined that church when he was 12 years of age and had remained active in its affairs throughout his life.

Mr. Thompson was elected an Associate Member of the American Society of Civil Engineers on June 6, 1927.

ROBERT BROWN MURPHY WILSON, Assoc. M. Am. Soc. C. E.*

DIED DECEMBER 15, 1928.

Robert Brown Murphy Wilson was born at Chatsworth, Ill., on January 2, 1883, the son of Charles A. and Amelia D. (Levering) Wilson. His father was, for many years, a banker in Chatsworth and was largely interested in real estate in that section of Illinois. He subsequently removed to Chicago, Ill., where he engaged in the stock brokerage business.

His grandfather, Dr. R. B. M. Wilson, was a native of Island Magee, near Belfast, Ireland. He was graduated in medicine from the University of Edinburgh, and directly thereafter came to America. Dr. Wilson settled in Washington, Ill., and was prominent in the practice of his profession throughout that section of the State until his death in 1879. Dr. Wilson's wife was Jane Anthony, of Sherburne, Vt., who when a child moved with her father to Illinois and through her, Robert Brown Murphy Wilson was descended from Josiah Wood, of Middleboro, Mass., who was a soldier in the Revolutionary Army.

On his mother's side, he traced his descent from Wiggard Levering who came to America from Leyden, Holland, in 1685, settling near Philadelphia, Pa., where he purchased land between the Schuylkill River and Wissahickon Creek. A portion of this land is now included in Fairmount Park, Philadelphia, and the Levering family has been continuously represented in this section of the latter city for nearly 250 years.

Mr. Wilson was graduated from the Chicago Manual Training School in 1900, and immediately entered the Engineering School of the University of Chicago with advanced standing; but, at the close of his Junior year, owing to various circumstances, he decided to enter the practical work of his profession and to qualify for his degree by outside study. He subsequently completed all his college requirements, except one subject, and was much commended for his proficient work in Spanish.

Mr. Wilson's first engagement was as Rodman on the construction of the Mobile, Jackson, and Kansas City Railroad in Mississippi, during 1902 and a part of 1903. During the latter year he secured an appointment as Surveyman in the United States Engineer District at Mobile, Ala., and was engaged on

* Memoir prepared by David G. Anderson, M. Am. Soc. C. E

hydrographic work in that vicinity for two years or more, except for a period of several months, when owing to the failure of Federal appropriations he was temporarily furloughed and accepted a position as Instrumentman with the Florida East Coast Railway Company. During the latter engagement he was occupied with reconnaissance work through the Everglades and from Key Largo to Key West, Fla.

For the next eight years, until 1913, he followed railroad work in Mexico. His first work there was in connection with the construction of the Colima Extension of the Mexican Central Railway, on which he served as Assistant to the Division Engineer. This Division represented very heavy construction and included both tunnel and bridge work. Subsequently, he was placed in charge of the extension of the Mexican Central Railway from Paredon to Saltillo, in the State of Coahuila, and, still later, of another extension from Marfil to Guanajuato, Mexico.

In 1909, Mr. Wilson became connected with the Southern Pacific Railway Company of Mexico, and served as Chief of Party on exploration work on the Yaqui River; Roadmaster on the Sinaloa Division; Assistant Superintendent, Maintenance of Way, on the Sinaloa and Sonora Divisions; and Engineer, Maintenance of Way, for all the Southern Pacific Lines in Mexico. His railroad work in Mexico was of the pioneering type and was attended with many difficulties.

For a time in 1913, he was interested in land development in Mexico, but in the following year he became connected with the Union Carbide Sales Company, as traveling representative, promoting the use of carbide in connection with the oxy-acetylene process.

Shortly after the entrance of the United States into the World War, Mr. Wilson entered the first Officers' Training Camp, at Fort Sheridan, Illinois, on May 13, 1917. He accepted a commission as Captain in the Engineer Officers' Reserve Corps on August 15, 1917, and was assigned to active duty the same day; he sailed for foreign service, September 9, accepted a commission as Major of Engineers on November 12, 1918, returned to the United States, June 27, 1919, and was honorably discharged on July 24, 1919, at Camp Grant, Illinois, while serving with the 311th Engineers.

On the completion of his war service Major Wilson resumed his connection with the Union Carbide Sales Company until 1921, when he became associated with the American Steam Conveyor Corporation, in Chicago. In 1923, he returned to Mexico and to the time of his death was General Manager of the Mina La Prinesa, a silver mine in Chilpancingo, Guerro, Mexico. His death, which was the result of several severe attacks of inflammatory rheumatism affecting the heart, occurred while he was a patient at the Evanston, Ill., Hospital, on December 15, 1928.

Major Wilson was a member of the Wilmette (Ill.), Presbyterian Church and took a deep and sincere interest in its work. During the periods when his professional duties permitted him to reside at home, he devoted himself to a boys' Sunday School class. He was conscientious in all his work, considerate and thoughtful toward others, and always to be remembered for his

cheery greetings and for the smiles that brought happiness to those with whom he came in contact. He never married, but was always a devoted son. He represented the finest type of a Christian gentleman, and was a worthy member of his chosen profession.

Major Wilson was elected an Associate Member of the American Society of Civil Engineers on June 30, 1911.

FREDERICK OLIVER MACY, Jun. Am. Soc. C. E.*

DIED DECEMBER 6, 1928.

Frederick Oliver Macy was born on May 10, 1905, at St. Croix Falls, Wis., the son of Elbert Clyde Macy, M. Am. Soc. C. E., and Minta Tilden Macy. Owing to the character of his father's business, that of a Construction Engineer, the boy's grade school education was obtained in the States of Washington, New York, and Iowa. A full four-year High School course was completed, however, in Ames, Iowa, at the home of his grandfather, Mr. Fred C. Tilden.

During this time, Mr. Macy showed the same devotion to study and the disposition to think clearly and accurately that characterized his later work in the university and in business. He took an active part in athletics while in High School and twice won the tennis medal. He played each year in the class basketball teams. He was a member of the track relay team in 1923 that took the National High School Medal. He was Athletic Editor of the High School paper during 1922-23, was Advertising Manager during his Senior year, and Manager for the Class Annual for his Class of 1924.

While attending the Ames schools he worked during the summer vacations of 1918 and 1919 as Transportation and Material Yard Clerk in the Hog Island Ship Building Yards near Philadelphia, Pa., and although young, thus served his country during the World War. In the summer of 1919 he worked as a Machinist Helper for the Great Western Power Company, in connection with the building of a power plant in the mountains of California.

From September, 1921, to July, 1922, Mr. Macy accompanied his family to Japan, China, and the Philippine Islands and worked with his father on proposed power developments. He thus began with practical experience a profession that he had chosen to be his life's work.

After finishing High School Mr. Macy entered Leland Stanford University at Palo Alto, Calif., where he took the civil engineering course and was graduated, with honors, in the Class of 1928. During vacations he was, in 1926, again employed at the scene of his earlier work, the enlargement of the Big Meadows Dam of the Great Western Power Company. In the summer of 1927, he was engaged on building construction in Los Angeles, Calif., and won the high esteem of his employers. His work at the University was of the highest order, which, together with his practical experience, gained in vacation periods both while in high school and in the University, won for him the opportunity to serve as Instructor in Surveying while still finishing his own course. Dur-

* Memoir prepared by Charles B. Wing and F. M. Thebo, Members, Am. Soc. C. E.

ing his Senior Year he was elected President of the Student Chapter of the Society and was chosen by his Class to represent it in presenting the bronze plate for the Class of 1928 to be placed in the Memorial Chapel.

Before his graduation, Mr. Macy was offered a responsible position in connection with making surveys and plans for a large water system to supply a group of cities in the neighborhood of San Francisco, Calif. His previous experience with a number of important engineering projects during his vacations was a guaranty of success here. He continued in this work until late in November, 1928, when he resigned to accept a position in connection with power plant work in Europe. While en route from San Francisco he was stricken with pneumonia and became very ill before reaching his grandfather's home in Ames. He was immediately removed to the Mary Greeley Hospital where every possible effort was made to meet the crisis, but on December 6, with his family about him, he slipped away just before noon.

Few young men have been privileged to look forward to a more promising place of service in his chosen profession and none enjoyed a more complete respect and love than "Ted" Macy. He had a genius for friendship, born of a native grace of manner which was a fit expression for the kindly consideration that he cherished for all his companions.

To know him was to be charmed and won by his frank friendliness and generous thoughtfulness. To share his life was to be stimulated. Had he lived he would have gone far in his profession. He had already advanced far in the high adventure of unselfish friendship.

Mr. Macy was elected a Junior of the American Society of Civil Engineers on October 1, 1928.

LOUIS ALFONZO PEDERSON, Jun. Am. Soc. C. E.*

DIED APRIL 5, 1929.

Louis Alfonzo Pederson, the only son of Mr. and Mrs. H. A. Pederson of Tucson, Ariz., was born at Saint David, Ariz., on June 6, 1903. He was educated in the public schools of Saint David and Bisbee, Ariz., and was graduated from the Saint David High School in 1922 with the highest honors of his class. Through his efforts in his High School career, he earned a scholarship at the University of Arizona.

Mr. Pederson began his engineering career in September, 1922, working as a Chainman for P. E. Fernald, U. S. Mineral Surveyor at Tucson, in which capacity he was engaged until April, 1923. From May to August, 1923, he was employed as Head Chainman for Mr. Fernald.

Mr. Pederson's parents moved to Tucson in the spring of 1923, and Mr. Pederson then attended the University of Arizona from September, 1923, to May, 1924, as a student in Civil Engineering.

In June, 1924, he accepted a position with W. R. Elliott, Consulting Engineer, of Phœnix, Ariz., and was employed by Mr. Elliott until February,

* Memoir prepared by A. F. Harter, Assoc. M. Am. Soc. C. E.

1925, in the capacities of Head Chainman, Rodman, and Draftsman, successively.

From March to June, 1925, Mr. Pederson was with the Beardsley Land and Investment Company, of Phœnix, as Rodman, Instrumentman, Calculator, and Draftsman on irrigation and power investigations in the vicinity of Phœnix, under the direction of A. F. Harter, Assoc. M. Am. Soc. C. E., being in charge of a party on topographic surveys for storage reservoirs on the Agua Fria River. From July, 1925, to June, 1926, he was in the employ of the City of Tucson, as Head Chainman, Instrumentman, and Sand Inspector. He was also employed on city sub-division work and on paving and sewer construction.

In June, 1926, he accepted a position with the Griggs Engineering Company, of Phœnix, assuming charge of all field work on the San Pedro Irrigation Project on the San Pedro River, at Benson, Ariz., under the direction of Mr. Harter. This consisted of all the preliminary surveys on this project, including re-establishment of section corners, topography over the entire area of about 40 000 acres of land, preliminary canal location, location of diversion dam and storage reservoir, bed-rock investigations at the storage dam and diversion dam, and the running of exclusion areas within the limits of the project. Mr. Pederson showed marked ability and was placed in charge of two parties. The field work was completed in April, 1927, at which time he was transferred to Phœnix, where he was employed by the Maricopa County Municipal Water Conservation District No. 1 on canal location and construction connected with the Lake Pleasant Dam on the Agua Fria River. He remained throughout the entire construction period, at all times in direct charge of important work which was completed in March, 1928.

Mr. Pederson's achievements during the construction period were appreciated to such an extent that on the completion of the undertaking he was retained in the Operating Department as Water Master in charge of the delivery of water to the irrigated areas and, after the irrigating season, he was transferred to the Phœnix Office as Computer and Draftsman. He was employed in this capacity at the time of his death.

His tasks always were carefully and accurately undertaken. Mr. Pederson was one of a group of young, far-sighted engineers who never slighted the work at hand; he was definitely aware and certain of the nature of each problem he attacked before plunging into it, regardless of its difficulty or intricacy. His field and office work stand as a fine tribute not only to himself but to the organization as well.

He was an ardent student at all times, having been enrolled with the Wilson Engineering Corporation, of Cambridge, Mass., and he was well advanced in this correspondence course at the time of his death.

He was unmarried and was affiliated with the Church of Jesus Christ of Latter Day Saints, of which he was a regular attendant.

Mr. Pederson was elected a Junior of the American Society of Civil Engineers on March 5, 1928.